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NATURE-BASED SOLUTIONS HANDBOOK

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CONTENTS

ABBREVIATIONS

AI: Artificial Intelligence
B2B: Business to Business
B2C: Business to Consumer
BENE: Berlin Program on Sustainable Development
BID: Business Improvement Districts
BMC: Business Model Canvas
CBA: Cost-Benefit Analysis
CEA: Cost Effectiveness Analysis
CFD: Computational Fluid Dynamics
DG-RTD: Directorate-General for Research and Innovation
DIAS: Data and Information Access Services
EC: European Commission
ECMWF: European Centre for Medium-Range Weather Forecasts
EGC: European Green Cities
EIA: Environmental Impact Assessment
EIB: European Investment Bank
EO: Earth Observation
EPRS: European Parliamentary Research Service
ERDF: European Regional Development Fund
ES: Ecosystem Service(s)
ESA: European Space Agency
ESIF: European Structural and Investment Funds
EU: European Union
EUMETSAT: European Organisation for the Exploitation of Meteorological Satellites
FP7: 7th Framework Programme for Research and Technological Development
FWS: Free Water Surface(s)
GEE: Google Earth Engine
GI: Green Infrastructure(s)
HAPS: High-Altitude Pseudo-Satellites
HSSF: Horizontal Subsurface Flow(s)
INTERREG: European Territorial Cooperation Programs
IT: Information Technology(ies)
IUCN: International Union for Nature Conservation
LCC: Life Cycle Costing
LIFE: Funding Instrument for the Environment
MAES: Mapping and Assessment of Ecosystems and their Services
MCA: Multi-Criteria Assessment
MEA: Millennium Ecosystem Assessment
MEBS: Method of Empathy-Based Stories
ML: Machine Learning

MODIS: Moderate Resolution Imaging Spectroradiometer
NASA: National Aeronautics and Space Administration
NBS: Nature-Based Solution(s)
NCFF: Natural Capital Financing Facility
NGO: Non-Governmental Organisation(s)
NI: Natural Infrastructure(s)
OECD: Organisation for Economic Co-operation and Development
PES: Payments for Ecosystem Services
PPGIS: Public Participation Geographic Information System(s)
PPP: Public-Private Partnership(s)
R&D: Research and Development
R&I: Research and Innovation
RTE: French Transmission System Operator
SDG: Sustainable Development Goal(s)
SME: Small and Medium-Sized Enterprise(s)
SUDS: Sustainable Urban Drainage System(s)
SUEWS: Surface Urban Energy and Water Balance Scheme
TSO: Transmission System Operators
U-TEP: Urban Thematic Exploitation Platform
UIA: Urban Innovative Actions
UN: United Nations
UNESCO: United Nations Educational, Scientific and Cultural Organization
UNISDR: United Nations Office for Disaster Risk Reduction
UV: Ultraviolet
VF: Vertical Flow(s)
VOC: Volatile Organic Compound(s)
WAVES: Wealth Accounting and the Valuation of Ecosystem Services
WBCSD: World Business Council for Sustainable Development
WSN: Wireless Sensor Network(s)

PROLOGUE

Handbook objectives

This Handbook has been developed in the framework of the ThinkNature project. Its main objective is to gather and promote state-of-the-art knowledge regarding Nature-Based Solutions (NBS), comprising a comprehensive guide to all relevant actors. To this end, each aspect of NBS is investigated, from project development to financing and policy making, and is presented in a concise and comprehensive way, in order to be easily understandable. Regarding the EU agenda around NBS, this Handbook contributes to:

- Expanding the knowledge base about the effectiveness of NBS,
- Supporting the implementation of NBS through enhancing their replicability and upscaling,
- Utilising the knowledge and experience of stakeholders, and
- Proposing a comprehensive methodological approach for innovation.

Recommendations for using the Handbook

The Handbook is highly recommended to all stakeholder groups that use NBS in their work, but it can also be useful for other organisations and individuals that comprise potential NBS stakeholders. Additionally, many chapters can contribute to increasing public awareness about NBS. In respect of the structure of the Handbook, each chapter focuses on a separate issue (analysed and documented through specific subtopics) and targets different types of NBS stakeholders. In general, Chapters 1-4 provide general background knowledge, useful for everyone involved in NBS initiatives; Chapters 5-7 are more specialised, addressing issues relevant to different NBS stakeholder groups (i.e. Chapter 5 for research and innovation, Chapter 6 for business sector, and Chapter 7 for policy sector); and Chapter 8 concludes with key recommendations. More specifically, the Handbook chapters deal with the following:

Chapter 1:
Introducing the concept of NBS, the overall framework of the challenges addressed, and the current efforts of building an NBS knowledge base.

Chapter 2:
Presenting and analysing the classification scheme, adopted by the ThinkNature project for categorising the various case studies that are documented in the project's portfolio.

Chapter 3:
Documenting the range and scale of benefits linked to the implementation of NBS and other issues towards their better understanding.

Chapter 4:
Describing the required methodological steps for achieving successful NBS implementation, as well as practical considerations and barriers and drivers.

Chapter 5:
Presenting innovative solutions regarding urban areas and the natural environment, as well as monitoring technologies.

Chapter 6:
Describing economic opportunities and risks, as well as instruments including financing mechanisms and efficient business models.

Chapter 7:
Focusing on policy and decision making; specifically on statutory barriers and drivers, the diverse spatial perspectives, and policy and decision-making proposals.

Chapter 8:
Key recommendations for overcoming barriers and bridging gaps in order to more effectively uptake and promote NBS.

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EXECUTIVE SUMMARY

Nature-based solutions (NBS) are actions inspired by, supported by, or copied from nature, that deploy various natural features and processes, are resource efficient and adapted to systems in diverse spatial areas, facing social, environmental, and economic challenges. The main goals of NBS are the enhancement of sustainable urbanisation (Figure ES.1), the restoration of degraded ecosystems, the development of climate change adaptation and mitigation, and the improvement of risk management and resilience. Moreover, NBS address global challenges, directly connected to the Sustainable Development Goals (SDG). NBS provide multiple benefits and have been identified as critical for the regeneration and improvement of wellbeing in urban areas, coastal resilience, multifunctional watershed management, and ecosystem restoration. They also increase the sustainability of matter and energy use, enhance the insurance value of ecosystems, and increase carbon sequestration.

The vision of the European Commission is to position the EU as a leader in nature-based innovation for sustainable and resilient societies. Establishing an NBS evidence and knowledge base, developing a repository of best practices, creating an NBS Community of Innovators, and improving communication and NBS awareness are the main actions to achieve this vision. The added value of the NBS knowledge repository would be better dissemination and visibility, and better uptake and mainstreaming of NBS, as well as contributing to and establishing lively Community of Practice. The evidence for NBS includes NBS case studies, business cases, facts and figures supporting NBS effectiveness and NBS added value, and successes and failures.

Figure ES.1. Vertical Forest realized in the centre of Milan, credited to the architect Stefano Boeri (https://oppla.eu/casestudy/17625)

ThinkNature case studies portfolio

Several FP7 (2007–2013) projects have already demonstrated the positive outcomes of NBS in practice. The dedicated focus area on 'Smart and Sustainable Cities with NBS' of Horizon 2020 invested in large-scale demonstration projects to explore innovative solutions to the challenges faced by European cities. These projects have provided and will provide the case studies necessary for the EU evidence base. The ThinkNature case studies portfolio currently contains more than 120 case studies. The case study portfolio analysis is primarily based on a multilevel classification approach to achieve a uniform and robust interpretation of the attributes, types, and innovative elements of the implementation of each case study. A newly developed and detailed NBS Classification Scheme is provided in Annex 1.

NBS are classified according to the degree of intervention/level and type of engineering into three types as follows: TYPE 1: no or minimal intervention in ecosystems, TYPE 2: NBS for sustainability and multi-functionality of managed ecosystems, TYPE 3: Design and management of new ecosystems. Most of the NBS applications in the ThinkNature case study portfolio (95%) are TYPE 2 or TYPE 3: 64%, and TYPE 2: 31% - and only a few (5%) are categorised as TYPE 1. Most of the applications in Type 2 (62%) are extensive urban green space management, followed by agricultural landscape management (22%), monitoring applications (14%), and coastal landscape management (2%). Similarly, 46% of the applications of Type 3 are intensive urban green space management, 27% urban planning strategies, and 14% urban water management, which suggests that 87% of Type 3 applications deal with urban areas.

The most prevalent NBS approaches in the portfolio are the ecosystem-based management, climate adaptation approaches, infrastructure related approaches, and community-based adaptation. The most prevalent NBS challenges to be addressed are green space management, public health and wellbeing, water management, and urban regeneration. More than half of the NBS cases do not provide any provisioning services, while very few provide raw materials for energy, fisheries and aquaculture, and water for drinking. As to regulation and maintenance services; local climate regulation, flood protection, maintaining populations and habitats, flood protection, and carbon sequestration are the most frequently provided services. Finally, most of the case studies provide cultural services with recreation and intellectual and aesthetic values the most prominent services. The case studies portfolio contains examples for approximately half of the NBS types presented in the NBS Classification Scheme.

The multiple and multi-scale benefits of NBS

NBS aim at multi-functionality, i.e. at producing several benefits simultaneously. This is the most important characteristic of NBS as compared to the so-called hard or grey infrastructure. The benefits are often interrelated. For instance, NBS can improve air quality (environmental benefit), which allows a decrease of diseases related to air pollution (health benefit), which in turn allows savings in healthcare (economic benefit). NBS also provide local benefits for disaster risk reduction and increasing resilience. Healthy ecosystems are important for hazard prevention and post-disaster recovery. Moreover, they provide local benefits for climate change adaptation and regional-global benefits for climate change mitigation.

Natural ecosystems, especially forests, peat bogs, and oceans, act as carbon sinks, but for man-made NBS the net CO^2 balance depends on the production, use, and end-of-life phases. While there are promising estimates about carbon sequestration by man-made NBS, the net carbon balance depends on the materials used and the type of management. An emphasis on recycled-instead of virgin-materials and fossil fuel free management improves the balance.

To critically evaluate all the consequences of deciding on certain kinds of NBS, NBS should be explored holistically, i.e. considered at different scales (temporal, spatial, social, etc.). For instance, introducing trees in cities is likely to bring benefits such as carbon sequestration and the decrease of heat island effect, but, at the same time it, may create emissions of VOC, allergic reactions, and fire risks. Thus, a thorough analysis according to local context is needed to select the right species, the spatial arrangement, and the appropriate amount of vegetation. Yet, every NBS should target preservation of indigenous flora or take advantage of assisted migration to protect species threatened by climate change.

Design – Build - Operate

NBS are complex and require detailed consideration of the various stages of project development (Figure ES.2). The three basic stages of an NBS project (i.e. planning, execution, delivery) should therefore be carefully developed, taking into account the following considerations:

- **Dynamic solutions:** nature-based projects build on dynamic ecosystem functions which may evolve over time; this introduces an element of uncertainty; the project design and implementation need to take into account the dynamic nature of the processes;

- **Multiple stakeholders:** NBS need to involve a wide spectra of stakeholders and this requires extensive consultation upfront;

- **Multiple designs:** there are typically several solutions that may be considered; optimization is essential;

- **Multiple benefits:** NBS is likely to create additional benefits not directly linked to the problem at hand; there is need for a methodology that accounts for all the benefits of a nature-based project;

- **Adaptive management:** the dynamic nature of NBS may require adjustments over time; adaptive management is therefore essential.

Nature-based projects clearly need to take these different dimensions into consideration throughout the project development steps, from idea to implementation. Monitoring and feedback are also the last-but crucial-steps that reflect the dynamics of NBS and the need for adaptive management.

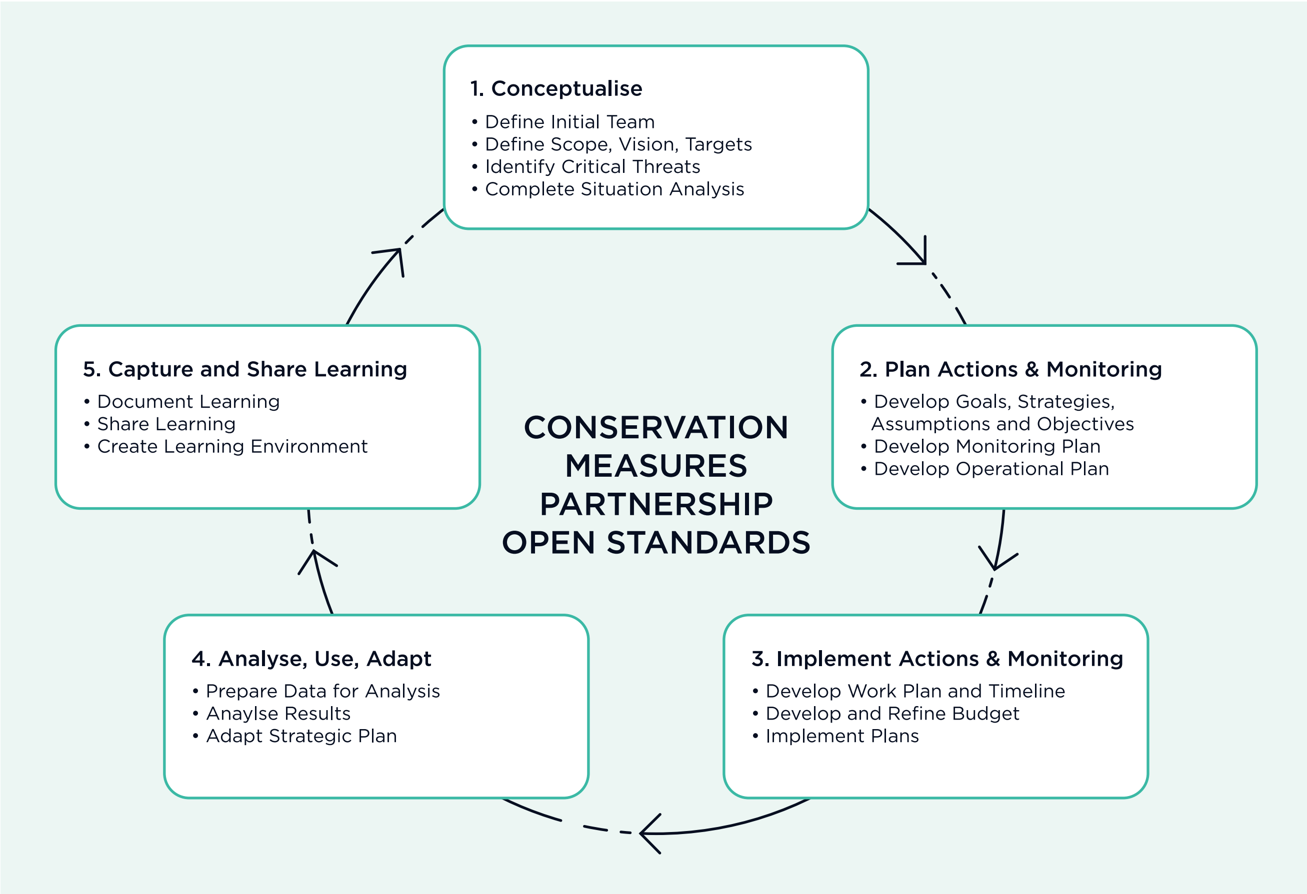

Figure ES.2. The adaptive management cycle (http://cmp-openstandards.org/)

Technical barriers and knowledge gaps

There are still multiple challenges for NBS projects. There is not considerable knowledge regarding designing, implementing, and maintaining NBS or quantifying (including economic valuation) the benefits and co-benefits of their ecosystem services. Moreover, there is a lack of deep understanding among key actors, and a deficiency of skills and experience in various levels of NBS project development. Decision makers and practitioners often lack the know-how to successfully address possible trade-offs and make optimal use of the available technical solutions. What's more, technically feasible solutions, appropriate to address multiple challenges, are limited, underdeveloped, and, in many cases, expensive. The lack of ready to use technologies and ready to apply scientific results and concepts, makes the adoption of NBS even more challenging.

There is also a lack of evidence of NBS effectiveness and the quantification of their environmental, economic, and social benefits. The insufficient, or in most cases absent, follow-up monitoring of implemented NBS impedes the evaluation of their effectiveness and, as such, deprives decision makers and practitioners from valuable conclusions concerning the cost-benefit analysis, the performance, and the longevity of NBS. The issue of monitoring the different scales of NBS impacts in both spatial and temporal dimensions, as well as the establishment of a common and holistic framework for the assessment of NBS impacts, are important directions for future research.

Technical innovation

There is an increasing trend for technical innovation in the field of NBS. Technical innovation is present in all types of NBS, but is focused more in the case of the design and management of new ecosystems. In the urban context, innovative solutions mostly concern smart engineering solutions, such as green roofs, urban farming, vertical gardens, green barriers, and sustainable urban drainage systems (SUDS). Outside the urban areas, there are large-scale applications for the design and management of new ecosystems. There is increased focus on agroecosystems, protected areas or parks, green corridors, wetlands, river basins, and coastal zones.

Constructed wetlands are good examples of innovative engineered NBS, designed and constructed to utilise the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in surface water, groundwater, or waste streams. River basin management techniques are also large scale NBS that have developed considerable innovation during the recent years to face risks due to excessive precipitation and prolonged periods of drought. Innovative schemes are also evident in coastal zone management to enhance coastal defence against climate change effects. In most cases, nature-based management and adaptation strategies based on natural processes help with adaption to climate change, restoration of the natural processes, strengthening of resilience, and reduction of flood risks.

New technological, research and innovation advancements are also emerging in the field of monitoring and quantifying the multi-scale NBS impacts. These advancements are expected to give enormous possibilities to assess the effectiveness of NBS and enhance the knowledge and evidence base.

Earth Observation (EO) technological and methodological advancements provide a unique capability of long-term, consistent, and multi-scale monitoring of environmental variables. In the framework of the Copernicus programme, solid databases of important in-situ and EO-based measurements, along with modelled parameters, are collected and provided across Europe and the whole globe, providing a unique potential for data harmonisation and standardisation. Cloud-based platforms, such as Copernicus DIAS and Google Earth Engine, provide centralised access to data and information, as well as to processing tools of unprecedented computing and modelling capabilities for both environmental and socioeconomic NBS impact assessment.

Financing of NBS

Economic opportunities for implementing NBS are there for the taking, but the system to enable the creation of the financial support for such schemes is not there in traditional business models. NBS are often more cost-effective than traditional grey infrastructure alternatives, but despite this, the barriers to their implementation are often more complex. These can be linked to management change, lack of education, partnership working, and securing investment for an emerging and less understood sector.

Defining a clear business case and securing financing for NBS is a prerequisite to their success, but these remain key barriers to those who wish to implement such schemes. Many struggle to articulate the multiple benefits of NBS in financial terms; this is a challenge due to limited or restricted data, limited research regarding quantified benefits, and a lack of coordinated knowledge transfer. These factors can in turn hinder the development of a well-defined business case.

Economic risk from an NBS project will vary with the type of solution, targeted resilience outcome, the level of investment, the scale of the actions, and the lifespan of the NBS. Performance measurement of an NBS will vary with the time and scale, leading to shifts in the level of resilience, and therefore risk mitigation of time. This can be either an improvement or deterioration in performance over time; and the level of acceptable risk will be affected by the level of return on investment. This is often difficult to distinguish for NBS, with significant side benefits often not quantified, monetised, or included in the business case or risk-return performance analysis.

The ways NBS are financed is a key consideration. In most cases, NBS are financed either by municipalities, regional authorities and national governments (public stakeholders), or by private companies and philanthropic organisations. The process of securing finances varies significantly across states and regions, as well as public and private entities. In many cases, there is a variety of forms of financing, depending on the local context and the willingness of the stakeholders to collaborate (WBCSD, 2017).

NBS in policy and decision making

NBS face multiple constraints in their implementation and thus require proactive and innovative policy interventions in order to be mainstreamed. Most policies on different levels (local, regional, national, and international) were developed without considering NBS as potential and comparable solutions to the conventional grey solutions or other similar means. As a result, the current policies can hinder or even prevent consideration of NBS projects. There is also limited knowledge on how to integrate and mainstream NBS into urban policies, planning processes, and decision-making mechanisms. As a next step, experts should focus on how to integrate NBS into relevant policies. Due to the multidimensionality and the multifunctionality of NBS, providing a variety of benefits, there is great potential to address the following challenges that most cities are facing nowadays: resilience, climate change adaptation, human health and wellbeing, social cohesion, and economic development. The implementation process shall be inclusive in a sense that multiple stakeholders participate in the planning process, including citizens, businesses, NGO, and the research community. An effective decision-making mechanism should allow informed, transparent, and ethical decisions, supporting sustainable development. Decision making results in the development of policies and can be part of the implementation process of a policy too.

On the (local) municipal level, there are many policy documents where NBS could be integrated, such as documents defining spatial development, strategic development, environmental protection, noise levels, low carbon economy plans, public transport development, and long-term financial forecast of a city. On the international (EU) level there are, for example, policy documents such as the EU Water Framework Directive, the Habitat Directive, and the Birds Directive, which set out the overarching framework for all the EU countries in order to properly address the subject of the matter in a comprehensive way. Relevant policies at all levels are essential because some problems might be solved on one level only. For example, tackling a city air quality might need interventions within the city, whereas tackling water pollution in rivers might need international collaboration.

KEY RECOMMENDATIONS FOR ENHANCED NBS UPTAKE
• Enhancement and harmonisation of the knowledge and evidence base on NBS towards the formulation of global NBS standards
• Development of adapted indicators for monitoring and evaluation
• Interaction across disciplines and adoption of participatory approaches
• Operationalisation of existing and new knowledge
• Efficient dissemination of knowledge
• Creation of funding opportunities and efficient business models
• Harmonisation of policies and facilitation of synergies across scales and across multiple agendas
• Innovative collaborations and governance systems

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

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1.1. The emerging concept of nature-based solutions

Nature-based solutions (NBS) is a novel **concept**, defined as actions inspired by, supported by, or copied from nature (Cohen-Shacham et al., 2016; EC, 2015) that:

- deploy various natural features and processes in a resource efficient and sustainable manner;
- are adapted to local systems into diverse spatial scales, redefining the role of nature in urban, rural, and natural environments; and
- face social, environmental, and economic challenges, leading to multiple benefits and supporting sustainable development and resilience.

The **use of NBS as a term** was initiated in the beginning of the 21st century and was adopted by several worldwide institutions during the next few years (Figure 1.1). Early on, the focus was on ecosystem-based initiatives, aiming at biodiversity conservation and environmental management (Eggermont et al., 2015). Progressively, economic and social considerations were also included, steering to further research on ecosystem services. Through this integrated approach, the role of nature in improving health and well-being, while promoting growth and job creation, was acknowledged. Since 2013, NBS has been widely adopted as a term and pushed forward in the EU Research and Innovation Policy agenda, so as to promote synergies between nature, society, and the economy (Cohen-Shacham, 2019).

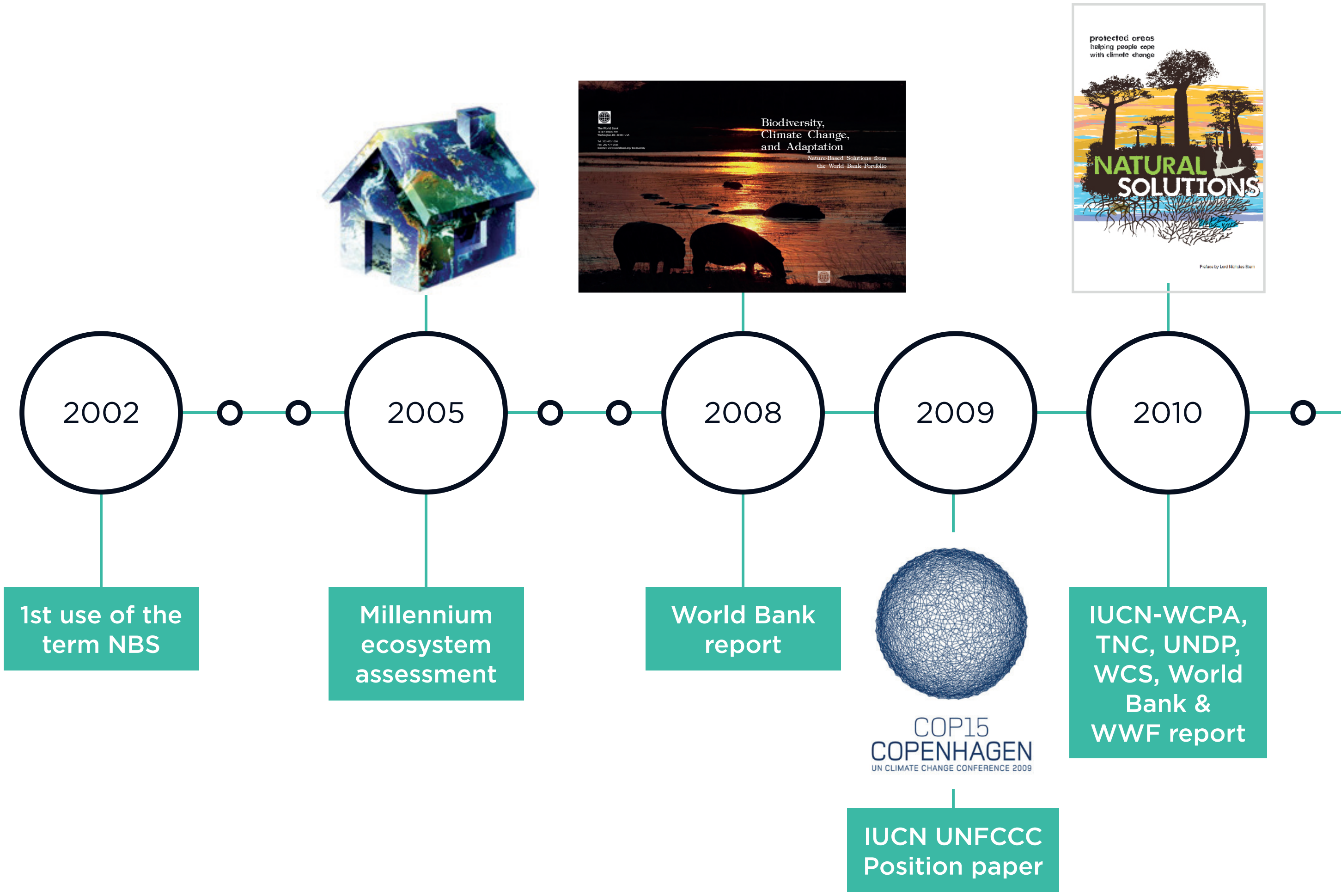


Figure 1.1. Timeline of the use of NBS as a term


NBS at core of EU Research and Innovation Programme
HORIZON 2020
European Commission
Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities
biodiversa
NBS workshop
thinknature
2013
2014
2015
2016
2017
2019
The IUCN Programme 2013–2016
NATURE-BASED SOLUTIONS
Nature-based Solutions to address global societal challenges
NBS2017
NATURE-BASED SOLUTIONS
From innovation to common use
NATURE-BASED SOLUTIONS INITIATIVE
IUCN work on NBS framework

In fact, NBS build on and endorse **earlier concepts**- such as ecological engineering and catchment systems engineering, green-blue infrastructure, natural infrastructure, ecosystem approach, ecosystem-based adaptation/mitigation, ecosystem services, renaturing, and natural capital- acting as an “umbrella” concept. These notions at a first glance appear to complement each other- but they are also diverse in terms of starting points, goals pursued, and perspectives (Nesshöver et al., 2016). However, all these concepts promote an integrated approach that considers ecosystems as a whole, without overlooking human activities and their effects, originating from population growth and surpassing impacts of nature (Steffen et al., 2015). In NBS, nature is the source of inspiration, offering sustainable alternatives for dealing with the effects of human activities and enhancing natural capital (EC, 2015).

NBS encompass many different kinds of actions and levels of intervention in ecosystems. Considering the degree/level of intervention and the type of engineering, the following three **main types of NBS** are identified (see Chapter 2 for more details):

• **Type 1 - Better use of protected/natural ecosystems**
Examples: protection and conservation strategies in terrestrial ecosystems, etc.

• **Type 2 - NBS for sustainability and multifunctionality of managed ecosystems**
Examples: extensive urban green space management, agricultural landscape management, etc.

• **Type 3 - Design and management of new ecosystems**
Examples: intensive urban green space management, urban water management, ecological restoration of degraded terrestrial ecosystems, etc.

The above-mentioned classification of NBS is indicative of the open nature of the term, a fact that poses certain difficulties, but also favours wider uptake. The challenge lies in defining “nature” and what is considered as “natural”. With many actions involving different levels and types of interventions, not all approaches can be classified as NBS. For example, the creation of vegetated roofs or walls in order to mitigate the Urban Heat Island cannot be considered as an NBS, if specific aspects such as biodiversity and sustainability are ignored (Eggermont et al., 2015). Moreover, several methods related to nature, such as genetically modified organisms and biomimicry, are excluded (Cohen-Shacham et al., 2016; EC, 2015).

1.2. Challenges and goals

NBS have a multi-functional role, which provides them great potential to address social, environmental and economic dimensions of global **challenges**. NBS have been identified as critical for the regeneration and improvement of wellbeing in urban areas, coastal resilience, multifunctional watershed management and ecosystem restoration, increasing the sustainability of matter and energy use, enhancing the insurance value of ecosystems, and increasing carbon sequestration (EC, 2015; Krauze & Wagner, 2019). NBS have especially been applied to address challenges, such as climate change mitigation, water management, land use, and urban development (Bulkeley et al., 2017) and they have been promoted by practitioners (in particular the International Union for Nature Conservation, IUCN) and through policy (EC), as a way for the sustainable use of nature in solving societal challenges (Eggermont et al., 2015). Furthermore, a link between NBS and cultural heritage, the fourth pillar of sustainable development[1], has also been established (Jurik et al., 2018). Cultural heritage along with NBS can promote sustainable growth of urban areas, productivity and socially and environmentally innovative solutions.
The idea of working with nature to innovate and address global challenges has been transformed into several **goals** and embedded in several reports and action plans, one of which is the Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'. As described in this report, the goals of NBS include (EC, 2015):

- **Sustainable urbanisation** – urban areas host an enormous share of the world population facing multiple challenges (natural resources shortage, human wellbeing, etc.).
- **Restoration of degraded ecosystems** – various ecosystems have been severely degraded due to human interventions and activities (agriculture, industry, etc.).
- **Adaptation and mitigation of climate change** – climate change is a worldwide challenge affecting not only environment but also economy and society.
- **Risk management and resilience** – there are diverse hazards, which can result in extreme losses for both natural and societal resources without the proper preparation.

[1] http://blogs.encatc.org/culturalheritagecountsforeurope/

Another action plan is the UN 2030 Agenda for Sustainable Development, which was adopted by all United Nations Member States (UN, 2015). It is comprised of 17 Sustainable Development Goals (SDG), tackling global challenges and putting pressure on the society, the economy, and the environment (Figure 1.2). Likewise, a principal objective of NBS is to address global challenges directly connected to the goals for sustainable development. NBS contribute to various UN SDG, and not only to those related to biodiversity and ecosystems. All around Europe, there are initiatives using NBS in relation to various SDG. Examples of connections of different types of NBS with SDG include (Faivre et al., 2017):

- Green investments can be linked to SDG 1 for tackling poverty.

- Urban agriculture is linked to SDG 2 for ensuring food security and improved nutrition.

- Urban ecological zones (e.g. green infrastructure) are linked to SDG 3 for health and well-being.

- Education based on NBS is linked to SDG 4 for inclusive and equitable quality education and promotion of lifelong learning.

- Natural water retention projects are linked to SDG 6 for the sustainable management of water.

- Climate adaptation strategies can be also linked to SDG 7 for sustainable energy.

- Innovative farming initiatives are linked to SDG 8 for sustainable economic growth as well as to SDG 1.

- Urban restructuring with NBS is linked to SDG 10 for reducing inequalities (social cohesion).

- Vegetated roofs and pocket parks are linked to SDG 11 for sustainable cities and communities (these solutions are also to connected to SDG 3, 10, and 13).

- Urban regeneration projects are linked to SDG 12 for ensuring sustainable consumption of resources (matter, energy, etc.).

- Urban green space planning is linked to SDG 13 for adapting to and fighting climate change.

- Natural coastal protection initiatives are linked to SDG 14 for the sustainable management of oceans and marine resources.

- Afforestation of rural areas is linked to SDG 15 which aims at protecting, restoring, and promoting sustainable use of terrestrial ecosystems as well as SDG 13.

- The creation of residential Green Corridors is linked to SDG 16 for the promotion of inclusive societies for sustainable development, as well as to SDG 3.

Figure 1.2. Presentation of SDG (https://sustainabledevelopment.un.org/sdgs)

1.3. EU initiatives for the promotion of NBS

The multifunctional concept of NBS has been identified by the European Commission as a strategic frame to support sustainability. Moreover, the vision of the EC is to position the EU as a leader in nature-based innovation for sustainable and resilient societies. Faivre et al. (2017) outlined the Research and Innovation roadmap of the Commission for promoting NBS at the European and international scale in order to establish the EU as a world leader on NBS:

- Establishing the NBS evidence and knowledge base - funding of the NBS demonstration projects was designed to develop the evidence and knowledge base to advance the development of NBS through innovation, co-design, co-implementation of solutions, and leverage of funding.

- Developing a repository of best practices - The ThinkNature template was designed to illustrate, in a systematic way, the design of NBS case studies and their benefits. This information is uploaded in Oppla[2] and it is available through the ThinkNature platform[3] as well.

- Creating an NBS Community of Innovators - through awareness and engagement (ThinkNature platform) organise NBS practitioners and users to further advance the development, uptake, and upscale of innovative NBS.

- Communication and NBS awareness - to promote NBS within the EU and international R&I agenda.

[2] oppla.eu
[3] platform.think-nature.eu

Regarding the EU's funding programs, there are H2020, FP7 (2007–2013) and other NBS projects, platforms, and networks that have been funded by the European Commission (Table 1.1 and Figure 1.3). FP7 (2007–2013) projects demonstrated approaches that use NBS in practice and the positive outcomes they can generate. Horizon 2020 provides new opportunities, including the dedicated focus area on 'Smart and Sustainable Cities with NBS', in which large-scale demonstration projects explore innovative solutions to the challenges faced by European cities (Faivre et al., 2017). A list and description of all the NBS funded projects can be found on the ThinkNature Platform. A brief description of the EU funded projects under the Research and Innovation action follows. These projects have provided and will provide the case studies necessary for the EU evidence base.

Table 1.1 EU initiatives for the promotion of NBS

RESEARCH AND INNOVATION ACTIONS AND PARTNERSHIPS	DIALOGUE PLATFORMS TO PROMOTE INNOVATION WITH NBS
Biodiversa (http://www.biodiversa.org/) CLEVER Cities (http://clevercities.eu/) Connecting Nature (https://connectingnature.eu/) EdiCitNET (https://cordis.europa.eu/project/rcn/216082_de.html) Eklipse (http://www.eklipse-mechanism.eu/) GRaBS (http://www.ppgis.manchester.ac.uk/grabs/) GREEN SURGE (https://greensurge.eu/) Grow Green (http://growgreenproject.eu/) Inspiration (http://www.inspiration-h2020.eu/) Nature4Cities (https://www.nature4cities.eu/) Naturvation (https://naturvation.eu/) NAIAD (http://www.naiad2020.eu/) OpeNESS (http://www.openness-project.eu/) OPERAs (http://operas-project.eu/) OPERANDUM (https://www.operandum-project.eu/) PHUSICOS (https://phusicos.eu/) proGIreg (http://www.progireg.eu/) RECONNECT (https://reconnect-europe.eu/) TURAS (http://r1.zotoi.com/) Unalab (https://www.unalab.eu/) URBAN GreenUp (http://www.urbangreenup.eu/) URBINAT (http://urbinat.eu/) ReNAture (http://renature-project.eu/)	ThinkNature (https://www.think-nature.eu/) Oppla (https:/www.oppla.eu/) EU Smart Cities Information System (SCIS) (https://www.smartcities-infosystem.eu/) EU Climate Adaptation Platform CLIMATE-ADAPT (https://climate-adapt.eea.europa.eu/) SUSTAINABLE CITIES PLATFORM (http://www.sustainablecities.eu/)

BiodivERsA is a network of national and regional funding organisations promoting pan-European research on biodiversity, ecosystem services, and Nature-Based Solutions. It supports the development of the knowledge base for the identification and implementation of Nature-Based Solutions and organises major opportunities for trans-national and trans-disciplinary research on synergies and trade-offs between multiple ecosystem services, between multiple stakeholders' views, and between ecosystem services and biodiversity, underpinning the NBS concept.

The **EKLIPSE** project is appointed to set up a sustainable and innovative way of knowing, networking, and learning about biodiversity and ecosystem services. EKLIPSE developed a first version of an impact-evaluation framework with a list of criteria for assessing the performance of NBS in dealing with societal challenges in order to conduct a comparison of different NBS (Raymond et al., 2017a; 2017b) and develop an assessment framework that can be used by demonstration projects in the design, development, implementation, and assessment of NBS in urban areas.

The **TURAS** project provided examples of solutions for building urban resilience, such as the development of modular, urban green walls that can be established almost anywhere and at a reasonable cost to local authorities.

The **GREEN SURGE** project developed the planning principles for how to develop urban green infrastructure. GREEN SURGE identified and developed ways of linking green spaces, biodiversity, people, and the green economy in order to meet the major urban challenges related to land use conflicts, climate change adaptation, demographic changes, and human health and wellbeing, and it also provided a sound evidence base for urban green infrastructure planning and implementation.

OpenNESS aimed to translate the concepts of natural capital and ecosystem services into operational frameworks that provide tested, practical, and tailored solutions for integrating ecosystem services into land, water, and urban management and decision making. It examined how the concepts link to, and support, wider EU economic, social, and environmental policy initiatives, and scrutinises the potential and limitations of the concepts of ecosystem services and natural capital.

OPERAs aimed to put cutting-edge ecosystem science into practice. Researchers and practitioners from 27 different organisations helped stakeholders to apply the ecosystem services and natural capital concept into practice. The successful combination of NBS with traditional solutions was demonstrated through one of the case studies from the OPERAs project. The project involved constructing and maintaining semi-fixed dunes on 15 km of Barcelona's urban coastline in order to optimise the flows of ecosystem services, and enhance coastal defence against sea-level rise. A systematic analysis of the beach management system led to a simpler and more cost-effective strategy, which integrates the building of natural capital and adaptation to climate change.

Projects such as **CONNECTING NATURE, GROW GREEN, UNALAB and URBAN GreenUP** are still ongoing and implement NBS for climate and water resilience in cities. These projects aim to demonstrate the benefits of re-naturing cities and to provide an EU-wide evidence base of the efficacy, efficiency, and comparative advantages of a range of tested, scalable, and easy-to-promote NBS. The findings of these projects support other ongoing projects, such as **Nature4Cities and NATURVATION**, which investigate new governance, business and financing models, and economic-impact assessment tools. The **NAIAD** project complements these actions by providing a robust framework for assessing the insurance value of ecosystem services. This is done by co-developing and co-testing - with key insurers and municipalities - the concepts, tools, applications, and instruments (business models) applicable, and making sure they can be used across all of Europe (Faivre et al., 2017).

OPPLA is an open platform for collaboration between communities of science, policy, and practice on natural capital, ecosystem services and NBS. At the same time, OPPLA is a knowledge forum where the outputs of research are made accessible to end-users, within and beyond the environmental sector. It offers a range of products, including a case-study finder, an ecosystem-service assessment support tool, as well as a 'Question & Answer' helpdesk. The helpdesk will complement the EKLIPSE 'call for requests' service, which invites policy and other societal actors to identify topics related to biodiversity and ecosystem services, where there is a need for more evidence, in-depth analyses, and a consolidated view from science and other knowledge holders. Complementing OPPLA, the **ThinkNature** platform is a multi-stakeholder dialogue platform and think-tank for promoting innovation with NBS. It brings multidisciplinary scientific expertise, policy, business, and society together to further increase knowledge exchange and capacity building.

OPERANDUM, proGIreg, RECONNECT, EdiCitNET, URBINAT, CLEVER Cities, PHUSICOS and RENature are the new EU funded projects. The OPERANDUM project develops NBS to mitigate the impact of hydro-meteorological phenomena in risk-prone areas. ProGIreg uses nature for urban regeneration with and for citizens, and stands for 'productive Green Infrastructure for post-industrial urban regeneration': nature for renewal. RECONNECT is a research project on 'Reconciling Europe with its Citizens through Democracy and the Rule of Law', aiming at understanding and providing solutions to the recent challenges faced by the EU. URBiNAT focuses on the regeneration and integration of deprived districts in urban development through innovative NBS

– an Urban Inclusive Nature – ensuring sustainability and mobilising driving forces for social cohesion; specifically, on “public space” and on creation of new urban, social, and nature relations with and between different neighbourhoods. The international European-funded CLEVER Cities project is launched by the city of Hamburg and a team of 33 other cities and organisations in Europe, South America, and China. Cities coordinate and lead the project and will use NBS to address social, economic, and environmental problems. The cities will bring in local residents and businesses to collaboratively decide, design, and build NBS in key districts affected by issues like high crime rates, social inequality, unemployment, and child poverty. PHUSICOS will demonstrate how nature-inspired solutions reduce the risk of extreme weather events in rural mountain landscapes. Finally, ReNature aims to establish and implement an NBS research strategy for Malta with a vision to promote research and innovation and develop solutions in a pursuit of economic growth, whilst at the same time improving human well-being and tackling environmental challenges.

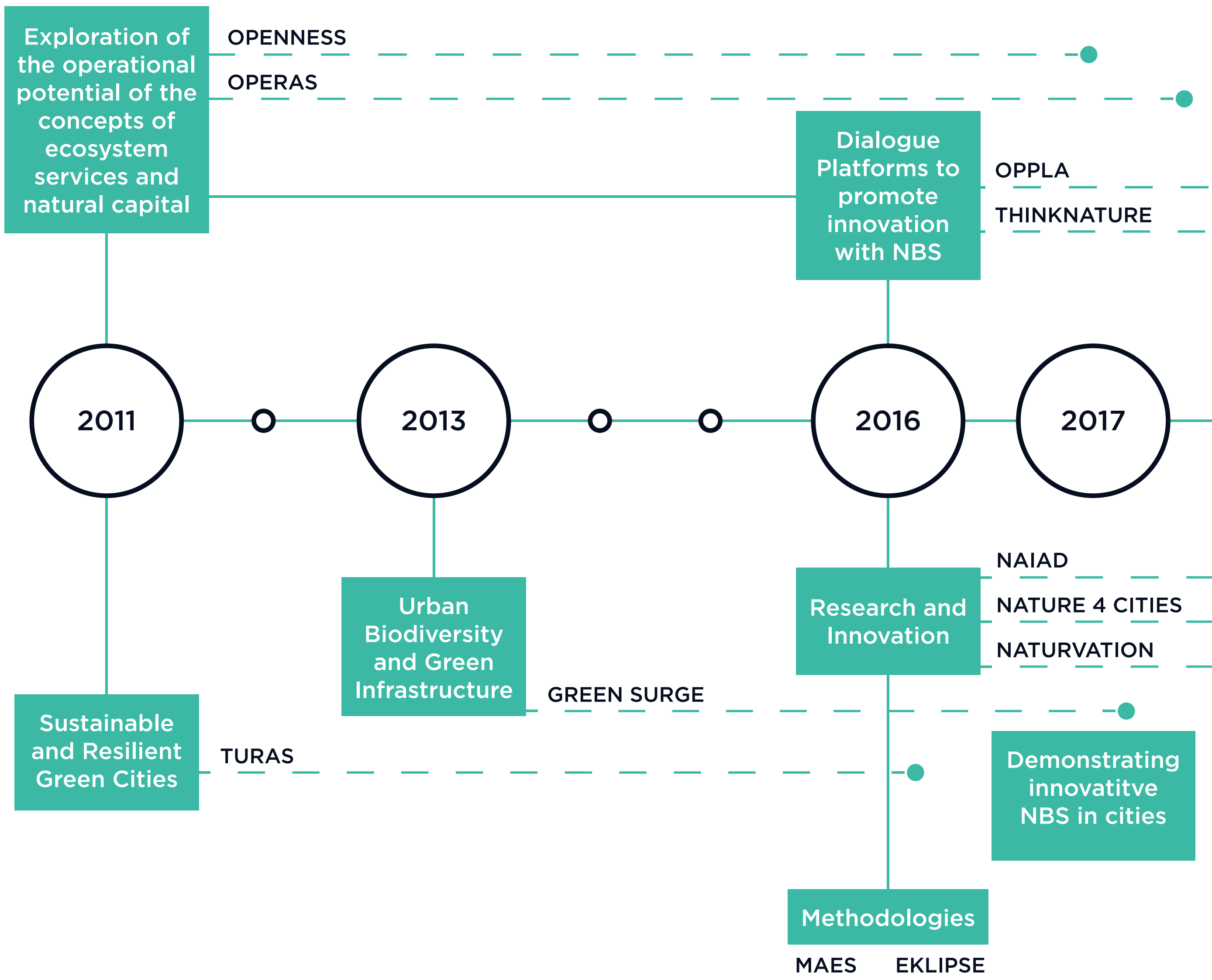
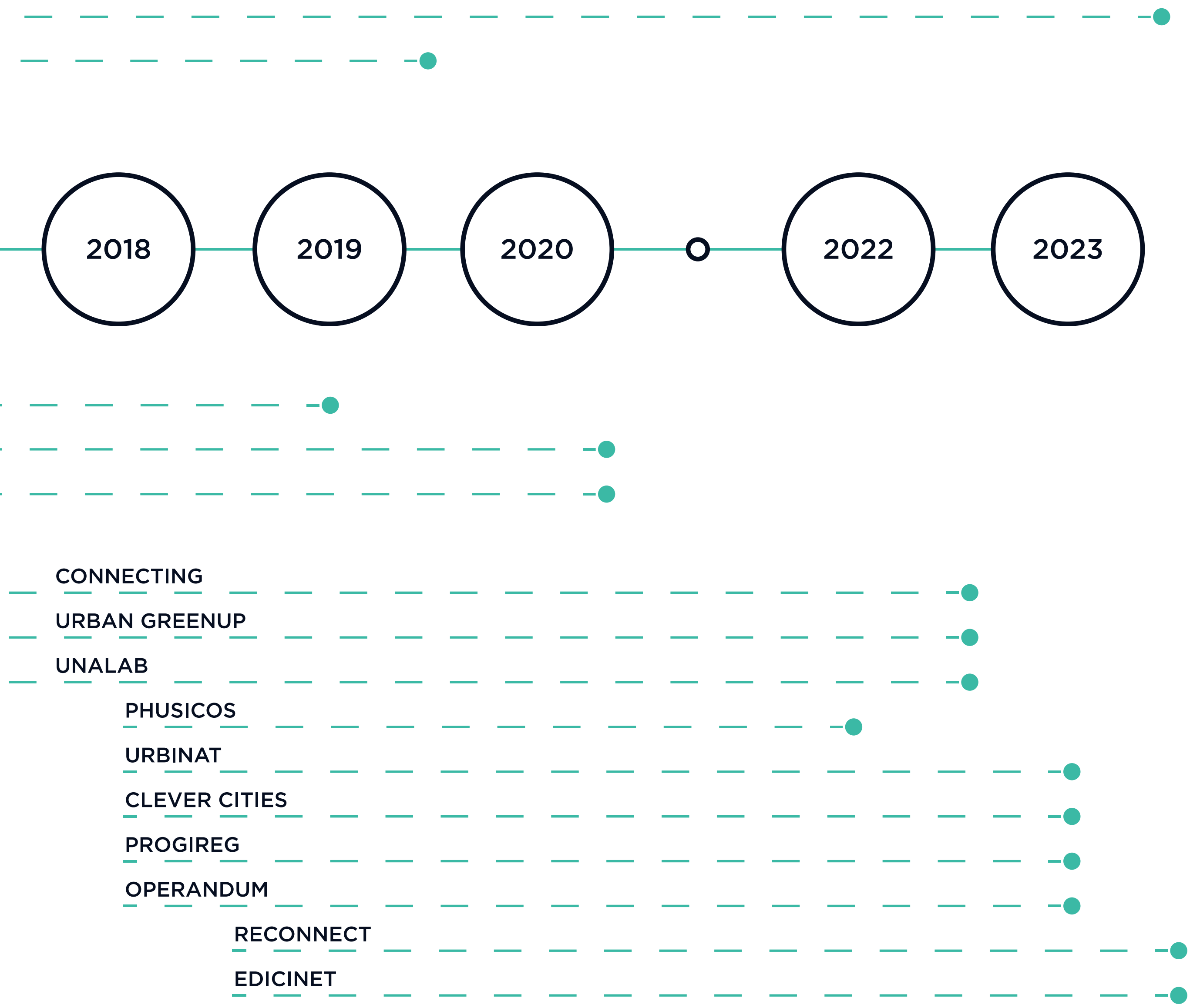


Figure 1.3. Timeline of NBS projects in the EU


2018
2019
2020
2022
2023
CONNECTING
URBAN GREENUP
UNALAB
PHUSICOS
URBINAT
CLEVER CITIES
PROGIREG
OPERANDUM
RECONNECT
EDICINET

CHAPTER 2
CLASSIFICATION OF NBS

2 CLASSIFICATION OF NATURE-BASED SOLUTIONS

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As it states in Chapter 1, the EC holds a crucial role regarding research and innovation (R&I) of NBS. The Horizon 2020 Expert Group report on 'Nature-Based Solutions and Re-Naturing Cities' (EC, 2015) stressed the need to develop a scientifically sound R&I programme, articulated around multi-stakeholder engagement and the **development of an evidence base for NBS**. The development of an integrated EU Evidence Base Repository aims to: 1) identify the type of data collected for EU evidence, 2) address issues with scale and levels of the data including the needs of the projects versus EU evidence, 3) develop data interoperability between NBS Demo projects.

An open access knowledge base for NBS will comprise of **evidence** for promoting NBS, as well as guidelines, tools, and methodologies for co-creation, implementation, and monitoring of NBS. Protocols and standards for evaluating NBS, such as the EKLIPSE NBS Integrated Evaluation Framework (Raymond et al., 2017a; 2017b), contribute towards this goal. The evidence for NBS includes NBS case studies, business cases, facts and figures, supporting NBS effectiveness and NBS added value, and successes and failures. The **Oppla**[1] and **ThinkNature**[2] platforms are being used to host this repository. The added value of such knowledge repository would be better dissemination and visibility, and imrpoved uptake and mainstreaming of NBS, as well as contributing to and establishing a lively Community of Practice.

The EC is using the evidence base resulting from the implementation of the various NBS demonstration projects to further **refine the concept of NBS** (Faivre et al., 2017). ThinkNature contributed towards this goal by developing an NBS case study template in collaboration with the EC and applying this template on the

[1] oppla.eu
[2] https://platform.think-nature.eu/NBS-knowledge-hub

online ThinkNature NBS case studies portfolio[3]. More specifically, the users can insert information on their case study following the specific format of the template and upload it on the Oppla repository[4], making it available on both platforms. The ThinkNature portfolio currently contains more than 120 case studies, collected and prepared by ThinkNature, the expert group of DG-RTD, current demonstration projects and several from former FP7 projects, (OPERAs, OpenNESS, TURAS, etc.).
To **extract useful informatio**n from the case study portfolio, an analysis methodology must be defined and implemented. ThinkNature adopted a multi-level approach for the analysis of the portfolio. The objective is to describe the portfolio content in a coherent manner, as well as to detect the main innovation elements and how these contribute to the EU knowledge repository on NBS. Moreover, the analysis aims to detect and specify the deficiencies of the current case study database in terms of diversity, representativeness, and information quality of the existing NBS case studies, documentation, and reports. Finally, analysis of case studies led to the development of an NBS classification scheme, which was used to assess the ThinkNature case study portfolio.

[3] https://platform.think-nature.eu/case-studies
[4] https://oppla.eu/nbs/case-studies

2.1. NBS Classification Scheme

The case study portfolio analysis is primarily based on a **multilevel classification approach** to achieve a uniform and robust interpretation of the case study attributes, types, and the innovative elements of its implementation. The adapted classification scheme was a result of a synthesis conducted from a literature review and stakeholder consultation/discussion on the ThinkNature platform. Each NBS type can be classified following four distinct approaches that all together identify the uniqueness and usefulness of the NBS. The four approaches are:

- **Approach 1 (A1)** - It is based on the NBS typology developed by Eggermont et al. (2015) considering the level and the type of engineering or management applied to biodiversity and ecosystems along with the number of ecosystem services delivered and the stakeholder groups involved.

- **Approach 2 (A2)** - The NBS approach classification shown in Table 2.1: ecosystem-based approaches, community-based approaches, ecological engineering approaches, etc.

- **Approach 3 (A3)** - The NBS challenge that it is expected to solve. These NBS challenges are also related to the United Nation's Sustainable Development Goals (SDG). The EKLIPSE Impact Framework challenges were followed in order to be consistent with the KPI's that are being established for the impact evaluation of NBS (EKLIPSE Impact Framework). Table 2.1 presents a list of the 10 NBS challenges to be solved.

- **Approach 4 (A4)** - The ecosystem services it is delivering (EC, 2015). Table 2.2 presents a list of major ecosystem services (MEA, 2005) used in terms of this classification.

Figure 2.1 presents a schematic with the proposed four classification approaches. In addition, the figure shows that each NBS type has been grouped into various NBS categories to further facilitate the classification. NBS type is defined as the actual, distinct NBS (e.g. green roofs), while in this case the NBS category is "intensive urban green space management". The multiple approaches provide more explicit information regarding the type of intervention, the setting, the actions, and the goals of the applied NBS.

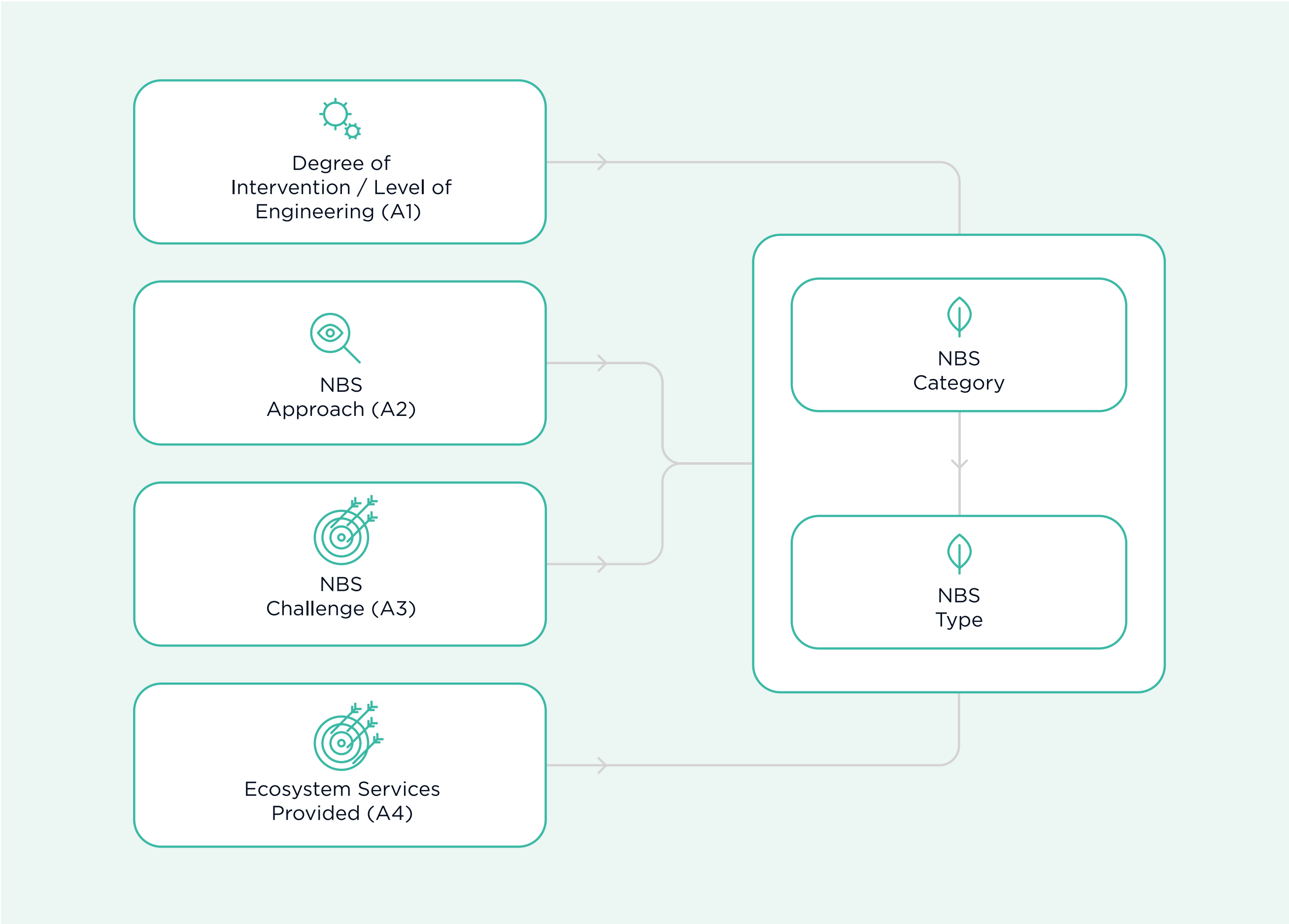


Figure 2.1. Schematic of NBS classification

Regarding the first NBS typology/classification (A1), the typology of Eggermont et al. (2015) was mainly used, classifying NBS into three types as follows:

TYPE 1 - no or minimal intervention in ecosystems - The objective of the action is to maintain or boost the effects of certain ecosystem services in already existing natural or weakly managed ecosystems. This type of NBS promotes better use of natural/protected ecosystems, implying the delivery of multiple ecosystem services to multiple stakeholder groups.

TYPE 2 - NBS for sustainability and multi-functionality of managed ecosystems - Effective management towards the sustainability and multifunctionality of ecosystems and landscapes so as to support selected ecosystem services. This type of NBS implies an increased provision of fewer ecosystem services to fewer stakeholders' groups.

TYPE 3 - Design and management of new ecosystems - A more transformational "intrusive" approach that is often connected to the creation of new ecosystems. Restoration of degraded ecosystems falls under this type. This type of NBS includes the design and management of new ecosystems, seeking to maximise the delivery of key ecosystem services for key stakeholder groups.

After **reviewing the typology of Eggermont et al. (2015)**, the adopted scheme by ThinkNature classifies NBS according to the degree of intervention/level and type of engineering in many (sub) categories, such as:

Type 1 – Better use of protected/natural ecosystems
- Protection and conservation strategies in terrestrial (e.g. Natura2000), marine (e.g. MPA), and coastal areas (e.g. mangroves) ecosystems

Type 2 – NBS for sustainability and multifunctionality of managed ecosystems
- Agricultural landscape management
- Coastal landscape management
- Extensive urban green space management
- Monitoring

Type 3 – Design and management of new ecosystems
- Intensive urban green space management
- Urban planning strategies
- Urban water management
- Ecological restoration of degraded terrestrial ecosystems
- Restoration and creation of semi-natural water bodies and hydrographic networks
- Ecological restoration of degraded coastal and marine ecosystems

The full classification scheme, including plenty of subcategories, is presented in Annex 1.

As for other projects and initiatives, the H2020 **Nature4Cities**[5] demonstration project has defined major NBS categories, which are also complementary to the Eggermont et al. (2015) typology. The Nature4Cities list of NBS was updated by experts from the ThinkNature platform to include NBS dealing with coastal areas and non-urban areas and they rearranged it regarding their classification into Type 1, 2 or 3, of the Eggermont et al. (2015) typology. Also, th e A2 and A3 have been used by the "**Nature Based Solution Initiative**" platform.[6]

[5] www.nature4cities.eu

[6] www.naturebasedsolutionsinitiative.org

Table 2.1. List of NBS approaches (A2) and challenges to be solved (A3)

NBS APPROACH	NBS CHALLENGE TO BE SOLVED / SDGS:
• Climate adaptation approaches • Community based adaptation • Ecosystem based adaptation • Ecosystem based management • Ecosystem based mitigation • Ecosystem based disaster risk reduction • Ecological engineering • Ecological restoration • Infrastructure related approaches • Natural resources management • Sustainable agriculture/agro-forestry/aquaculture	• Climate mitigation and adaptation • Water management • Coastal resilience • Green space management • Air quality • Urban regeneration • Participatory planning and governance • Social justice and social cohesion • Public health and well-being • Potential of economic opportunities and green jobs

Table 2.2. List of ecosystem services (A4)

ECOSYSTEM SERVICES PROVIDED:		
PROVISIONING SERVICES	REGULATION & MAINTENANCE	CULTURAL
• Fisheries and aquaculture • Water for drinking • Raw (biotic) materials • Water for non-drinking purposes • Raw materials for energy	• Carbon sequestration • Local climate regulation • Water purification • Air quality regulation • Erosion prevention • Flood protection • Maintaining populations and habitats • Soil formation and composition • Pest and disease control	• Recreation • Intellectual and aesthetic appreciation • Spiritual and symbolic appreciation

2.2. Case study portfolio analysis

The case study portfolio currently consists of 122 case studies. These case studies have been contributed by:

- 16 case studies by DG-RTD
- 19 case studies by past FP7 projects
- 31 case studies by the Demo projects
- 56 case studies collected by ThinkNature

Annex 1 presents the classification scheme in detail, according to which a total of 109 NBS types have been identified (8 Type 1, 35 Type 2, and 66 Type 3). Also, Annex 2 presents a list of the NBS types assigned to the case study portfolio and the NBS approach they use, the challenges they address, and the ecosystem services they provide. The case studies portfolio contains examples for about half of the NBS types presented in the NBS Classification Scheme (55 from 109). In fact, the case studies cover 5 out of the 8 NBS listed under Type 1, 21 out of 35 for Type 2, and 29 out of 66 for Type 3. These examples of NBS cover all the main categories of the scheme that classifies NBS according to the degree of intervention/level and type of engineering.

This classification scheme is applied to all the available case studies and the multilevel information is extracted in a **consolidated manner** for determining the respective statistics. It is used for detecting the trends regarding the types of applied NBS and potentially the gaps of the existing portfolio regarding the representativeness of the different habitats or settings.

These case studies correspond to 157 applied NBS types, since several case studies contain more than one NBS type. Figure 2.2 presents the statistics of A1 classification. Only 5% of the NBS applications are Type 1, 31% are Type 2, and 64% are Type 3. All case studies under Type 1 fall under the protection and conservation strategies. Most of the NBS applications in Type 2 (62%) are extensive urban green space management, followed by agricultural landscape management (22%), monitoring applications (14%), and coastal landscape management (2%). Similarly, 46% of the NBS applications in Type 3 are intensive urban green space management, 27% are urban planning strategies, and 14% are urban water management, which suggests that 87% of Type 3 NBS applications deal with urban areas.

Figure 2.3 presents the breakdown of NBS in the top three most popular categories of Type 2: agricultural landscape management, extensive urban green space management, and monitoring. The most represented NBS types under the agricultural landscape management category are “increase soil water holding capacity and infiltration” (19%), “soil improvement and conservation measures” (14%), and “agroecological network structure", "agroforestry", "enrichment planting", and "agro-forestry" (10% for each). The NBS types that ensure continuity with ecological network and planning tools to control urban expansion (26% for each) are the most represented in the extensive urban green space management category. Finally, ecosystem services valuation methods and assessment of NBS benefits (38% for each) are the most represented in the monitoring category.

Figure 2.4 presents the breakdown of NBS in the categories of Type 3: large parks, green roofs, and community gardens represent 45% of the intensive urban green space management, while 58% and 27% respectively are the urban planning strategies that account for distribution of public green spaces, and planning tools for climate change. Sustainable urban drainage NBS account for 52% of the urban water management, and 38% of it corresponds to the urban blue infrastructure. Regarding ecosystem restoration, the top three NBS types are planting trees and hedges, river or stream restoration, and re-establishing intertidal habitat.

Figures 2.5, 2.6, and 2.7 present the number of NBS applications that used a specific NBS approach (A2), addressed specific challenges (A3), and provided specific ecosystem services (A4). The most prevalent NBS approaches were the ecosystem-based management, climate adaptation approaches, infrastructure related approaches, and community-based adaptation. The most prevalent NBS challenges to be addressed were green space management, public health and wellbeing, water management, and urban regeneration. Challenges related to coastal resilience and potential for economic opportunities were the least common among the analysed case studies.

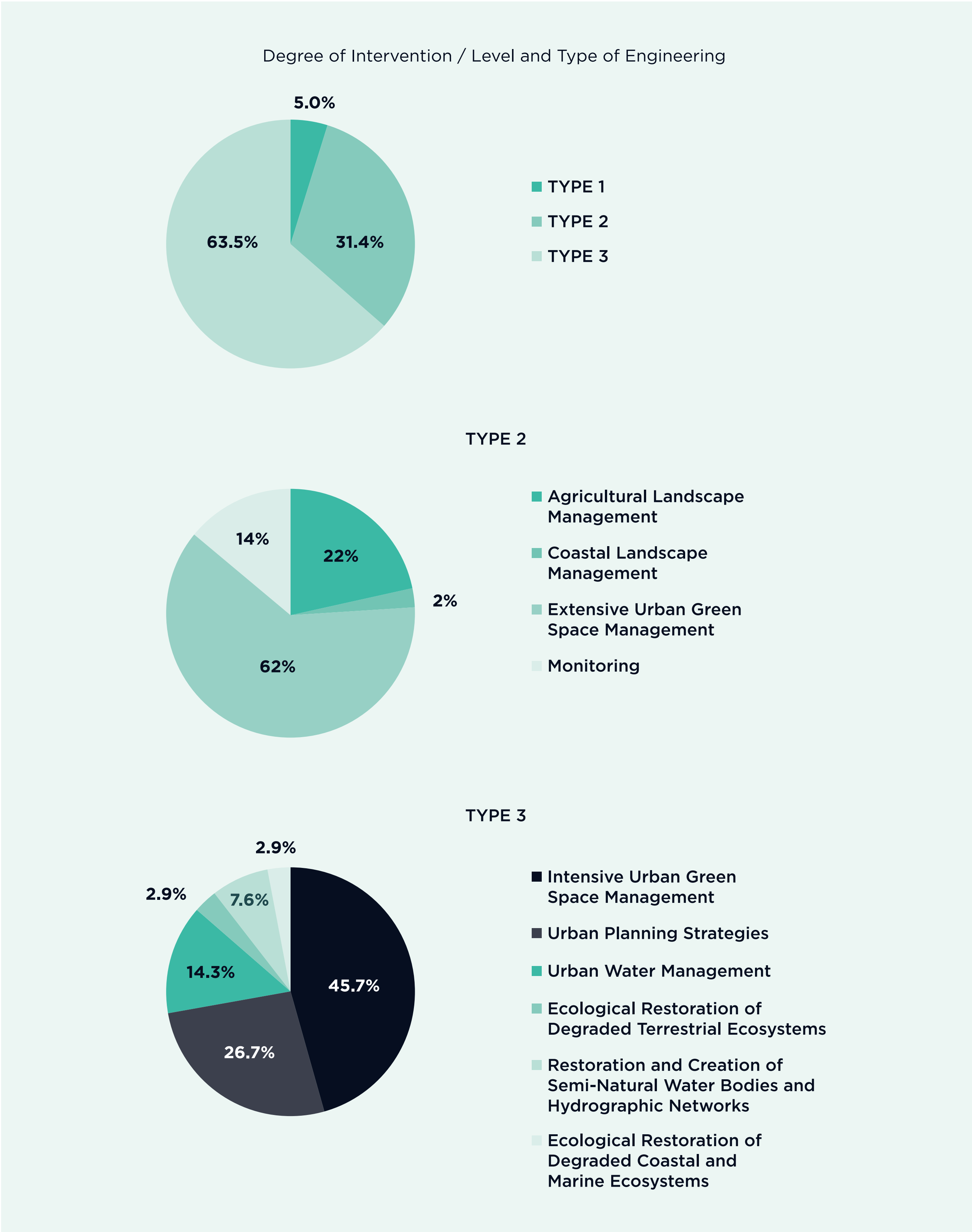


Figure 2.2. Statistics on the type of NBS based on the A1

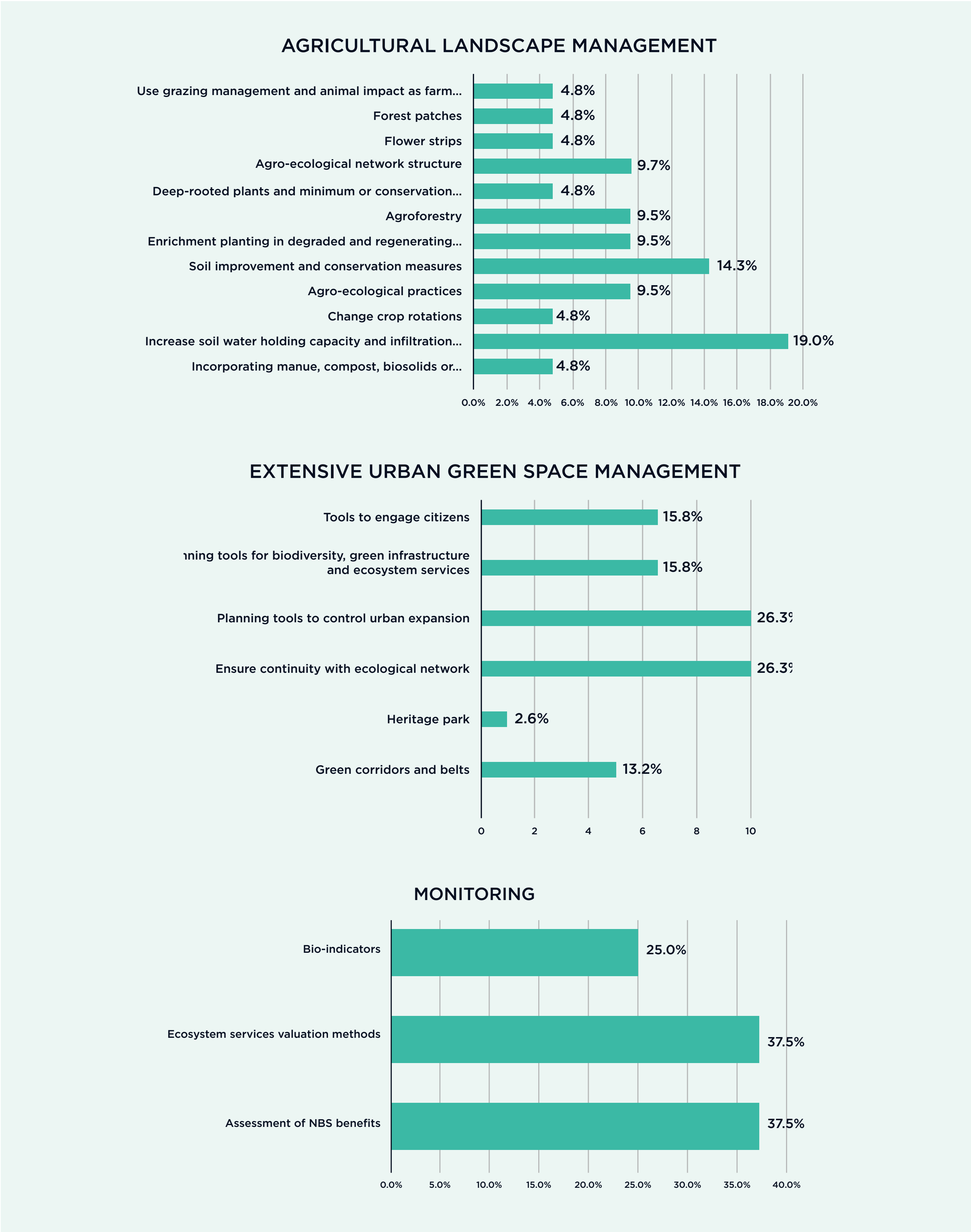
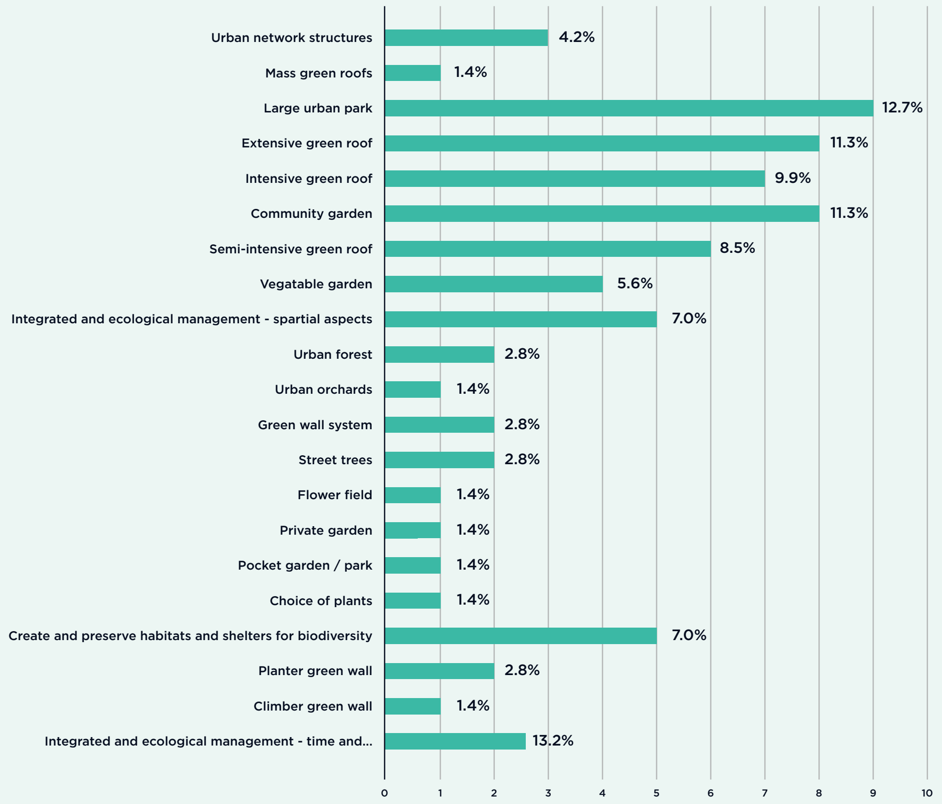
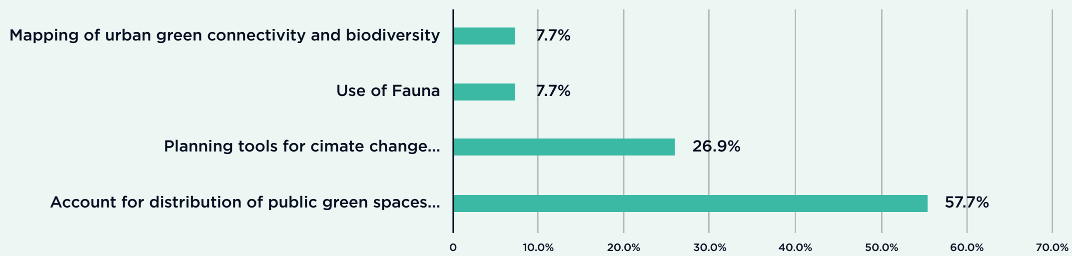


Figure 2.3. Statistics on Type 2 classification of NBS (A1)

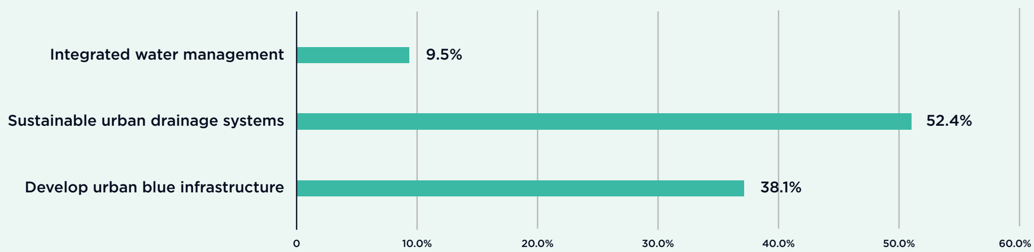
INTENSIVE URBAN GREEN SPACE MANAGEMENT



URBAN PLANNING STRATEGIES



URBAN WATER MANAGEMENT



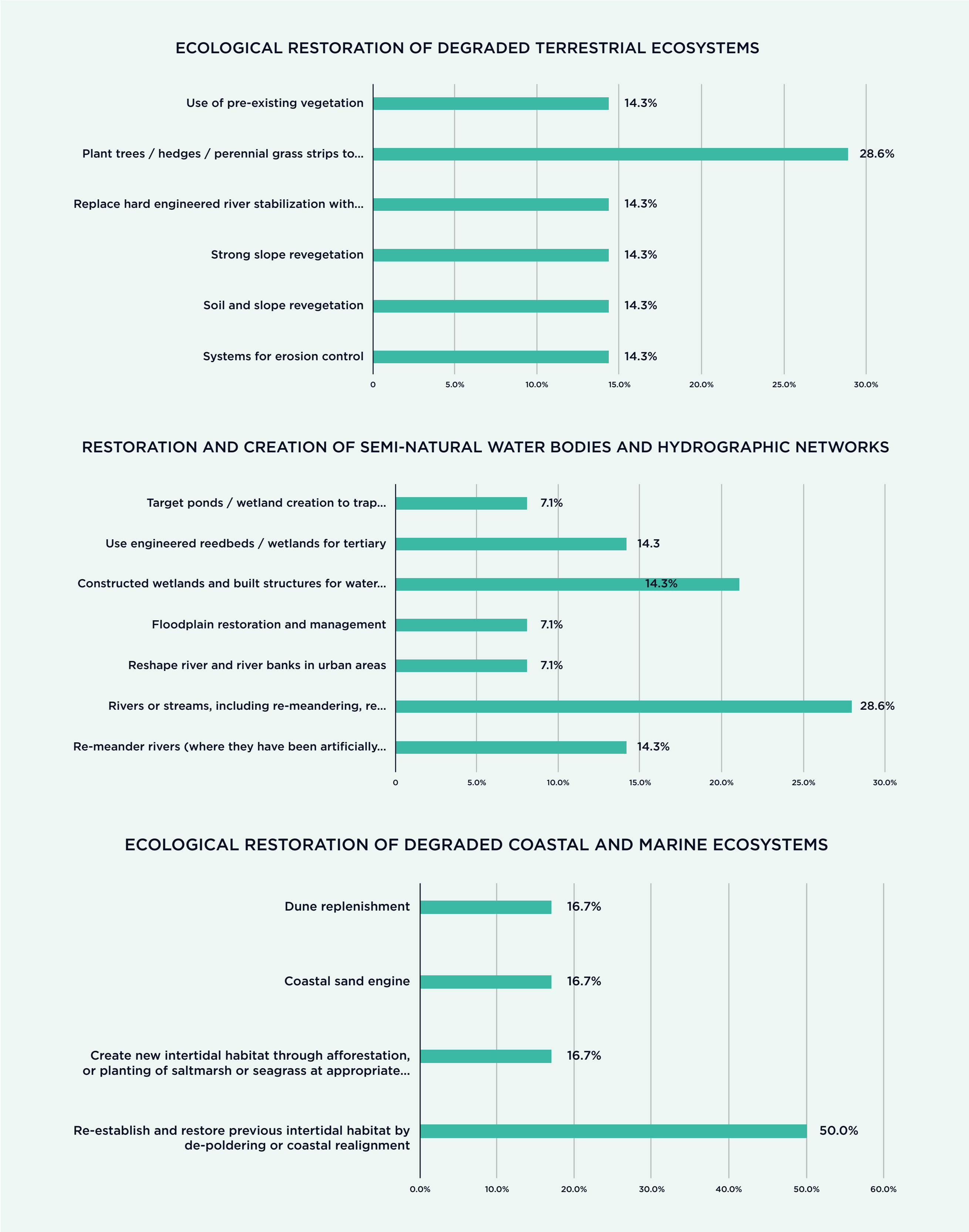


Figure 2.4. Statistics on Type 3 classification of NBS (A1)

The last type of characterisation (ecosystem services provided) includes three diverse categorisations according to provisioning services, regulation and maintenance, and cultural services (Figure 2.7). Regarding the first categorisation, more than half of the NBS cases do not provide any provisioning service, while very few provide raw materials for energy, fisheries, aquaculture, and water for drinking. This result indicates that direct service provision is rarely a principal target when planning and implementing NBS. As to regulation and maintenance services, local climate regulation, flood protection, maintaining populations and habitats, and carbon sequestration were the most frequently provided services among the documented NBS, designating the crucial role of these practices for the environment. Finally, most of the case studies provide cultural services, with recreation and intellectual and aesthetic values the most prominent services.

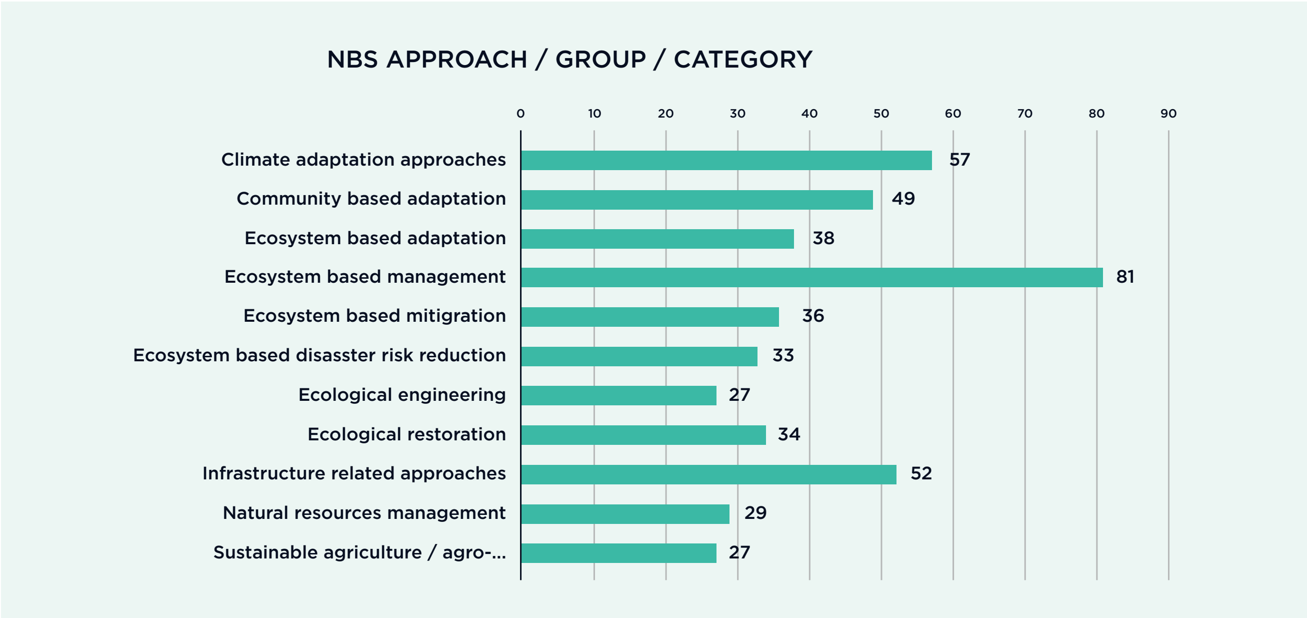


Figure 2.5. Number of NBS applications that used the specific approach (A2). Note: each application can address multiple approaches

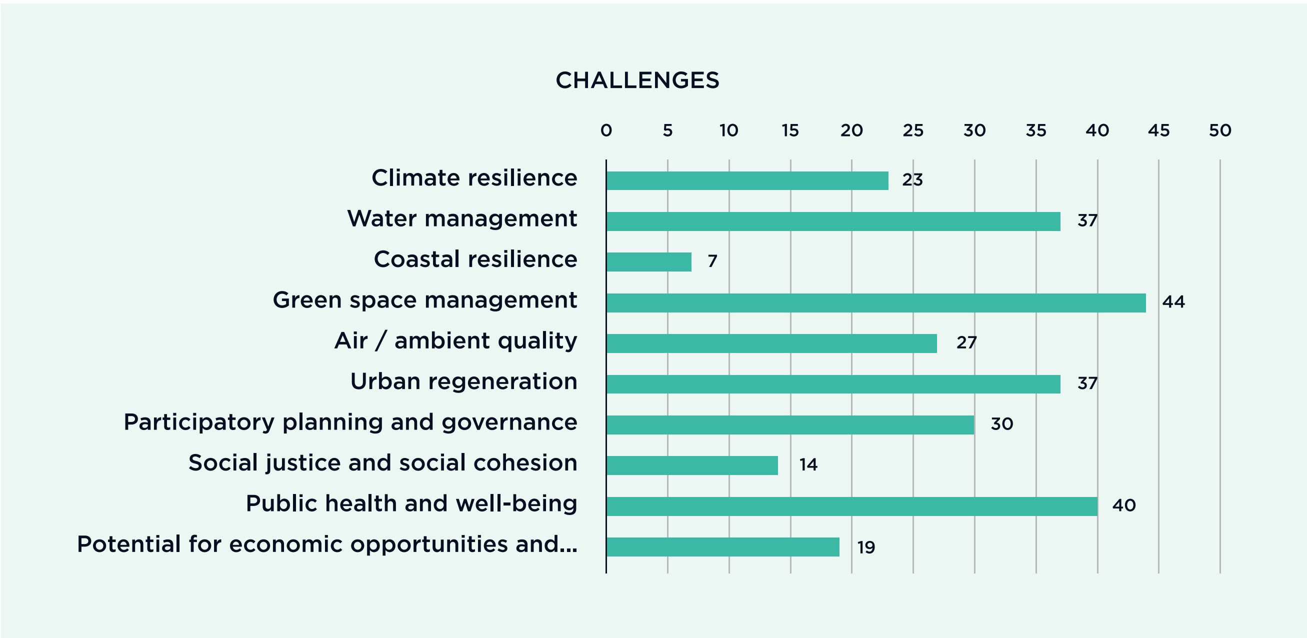


Figure 2.6. Number of NBS applications that address a specific challenge (A3). Note: each application can address multiple challenges

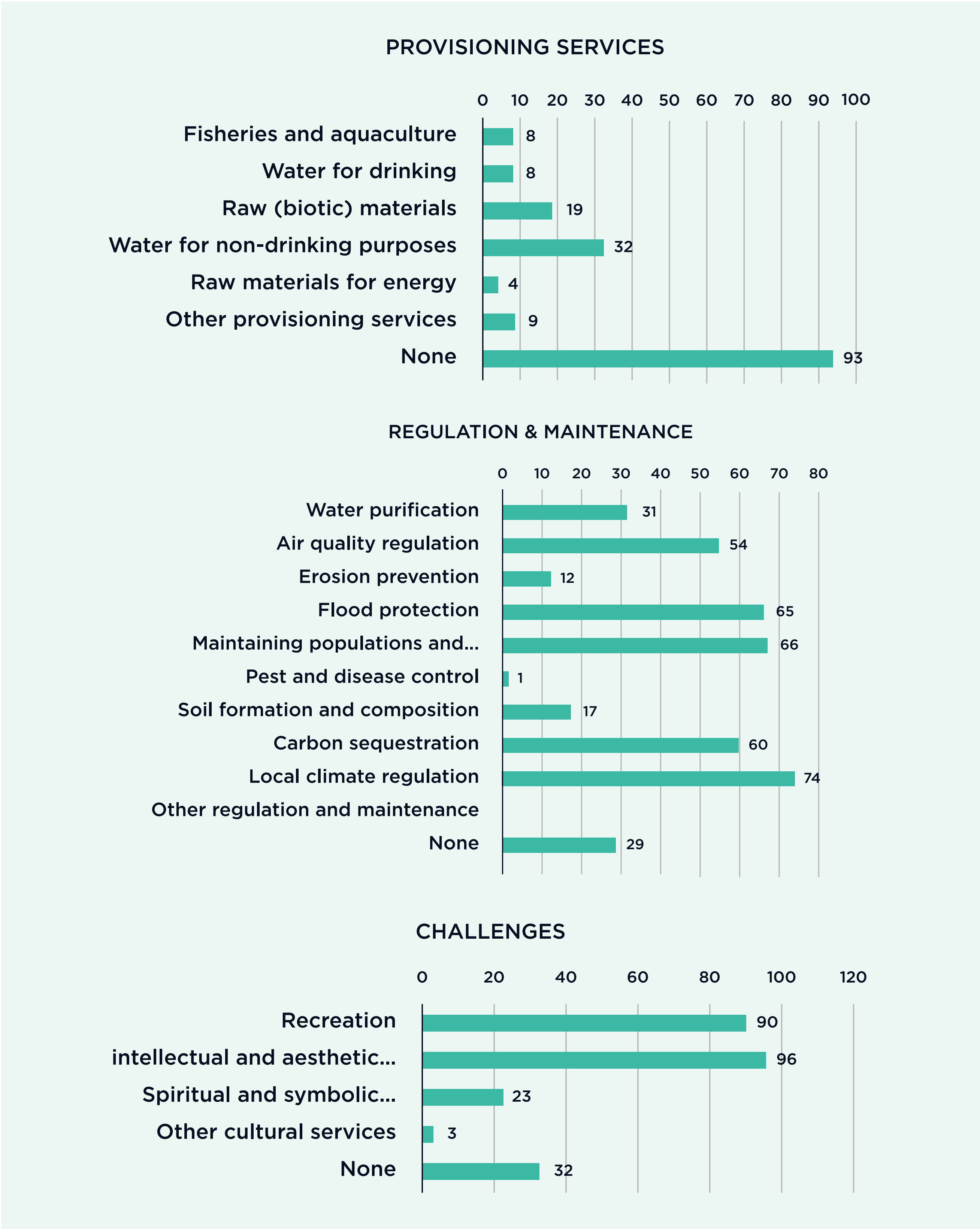


Figure 2.7. Number of NBS applications that provide the specific ecosystem service (A4). Note: each application can address multiple ecosystem services

Moreover, the analysis of the available case study information revealed useful remarks about the completeness and usefulness of the information provided in the submitted case study templates. This was assessed by defining four quality indices as described in Nikolaidis et al. (2019). The submitted information was found to be almost complete in terms of aspects covered, but in many cases insufficient in terms of usefulness to the EU knowledge base (Figure 2.8)[7]. Many case studies efficiently report their planning and designing context including decision making and project management aspects. However, there is a considerable deficiency in documented benefits, recognised barriers, clear suggestions on strategies to overcome barriers, and insights regarding the transferability of NBS. Only a few of the case studies report some impact evaluation scheme, given that nearly all the case studies were implemented before the initiation of the NBS impact evaluation framework initiative. Moreover, the existing information does not include results from the ongoing large-scale demonstration projects funded under Horizon 2020 (See Chapter 1).

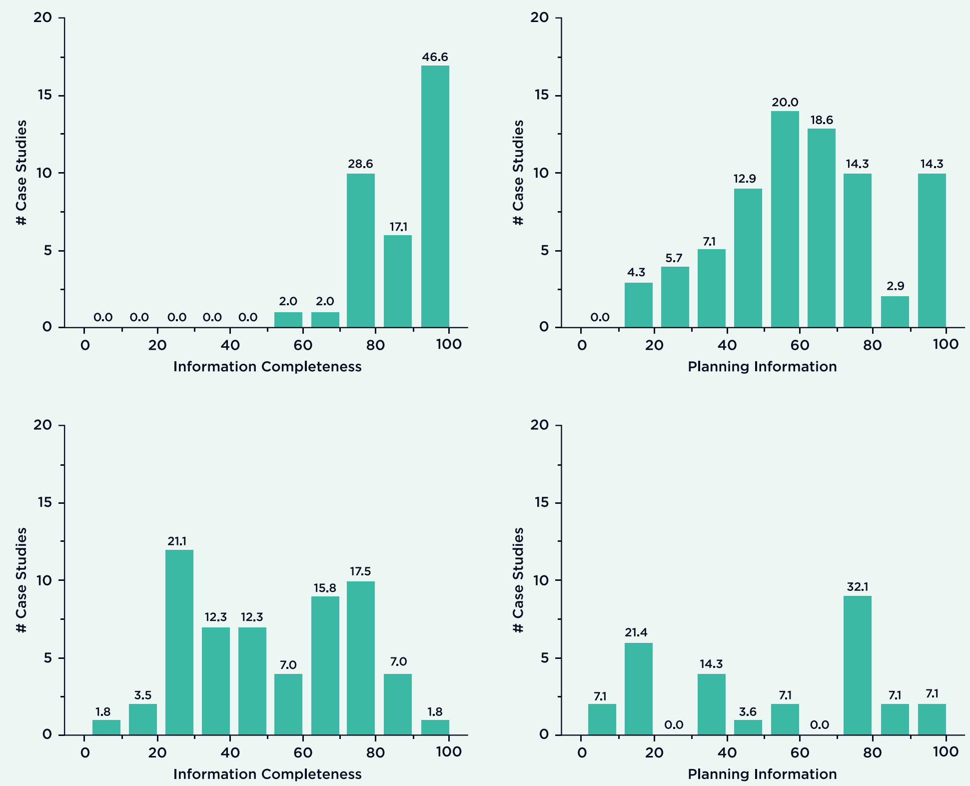


Figure 2.8. Histograms of the quality indices of the case studies portfolio. The number of case studies is shown in y axes and the percentage is shown in labels over each bar

[7] It should be noted that implementation information and especially impact information not calculated for all the case studies, as there are many unimplemented case studies and even more do not include measured impacts.

In conclusion, the **most important results** from the portfolio analysis can be summarised as follows:

- Most of the NBS applications (95%) are Type 3 (64%) and Type 2 (31%) and only a few (5%) are categorised as Type 1. Most of the applications in Type 2 (62%) are extensive urban green space management, followed by agricultural landscape management (22%), monitoring applications (14%), and coastal landscape management (2%). Similarly, 46% of the applications of Type 3 are intensive urban green space management, 27% are urban planning strategies, and 14% are urban water management, which suggests that 87% of Type 3 applications deal with urban areas.

- The most prevalent NBS approaches were the ecosystem-based management, climate adaptation approaches, infrastructure related approaches, and community-based adaptation. The most prevalent NBS challenges to be addressed were green space management, public health and wellbeing, water management, and urban regeneration. Challenges related to coastal resilience and potential for economic opportunities were the least common.

- More than half of the NBS cases do not provide any provisioning services, while very few provide raw materials for energy, fisheries aquaculture, forand maintenance services, local climate regulation, flood protection, maintaining populations/habitats, and carbon sequestration were the most frequently provided services. Most of the case studies provide cultural services, with recreation and intellectual and aesthetic values the most prominent services.

- Finally, the case studies portfolio contains examples for about half of the NBS types presented in the NBS classification scheme (55 from 109). These examples of NBS cover all the main categories of the scheme that classifies NBS according to the degree of intervention/level and type of engineering.

CHAPTER 3

MULTIPLE & MULTI-SCALE BENEFITS

3 MULTIPLE & MULTI-SCALE BENEFITS

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NBS aim to produce multiple benefits through multifunctionality. This chapter presents the different kinds of benefits or ecosystem services that can be gained by using NBS. It is important to note that these benefits cannot be isolated. Instead, every NBS likely provides multiple simultaneous benefits. However, NBS also consume natural resources and may at worst produce some unwanted impacts and ecosystem disservices, if they are not planned and installed carefully. Thus, possible negative impacts are also described in this chapter. In the end, a few interesting cases are presented, serving as a source of inspiration for their provided benefits.

In order to provide ideas and insights into the multiple scales and avoid unwanted impacts of NBS, two extensive tables (Tables 3.1 and 3.2) are nested in the following text, exemplifying important issues to consider in the evaluation and planning phases of an NBS. The tables should be seen as a source of inspiration, to promote independent thinking, instead of being exhaustive lists of all possible issues. Therefore, the tables are not fully streamlined in terms of categories. Instead, they portray the heterogeneity in categorisations that exist in scientific literature and practice.

While this chapter reviews the NBS benefits at different spatial scales and possible unwanted impacts, Chapter 4 provides ideas for approaching the complex situation of assessing multi-purpose NBS, in order to recognise the desired benefits as well as to mitigate or avoid unwanted impacts. Finally, economic benefits are described in Chapter 6, so they are not analysed in this chapter, but some aspects of them are included as examples in this chapter's tables.

3.1. Benefits at different scales

NBS concept constitutes an approach, where nature is seen as a source of solutions (see Chapter 1.1). In concrete terms, NBS offer an opportunity to consciously aim to provide multiple benefits for people investing in, residing in, working in, or spending their time in any given landscape. While a range of NBS benefits are presented in Table 3.1, it is important to emphasise that **multifunctionality**, i.e. the capacity to produce several services simultaneously at the same locality, is probably the most important attribute of NBS in comparison to grey infrastructure.

NBS should be explored **holistically**, i.e. considered in all their scalar dimensions, in order to understand all the consequences of deciding on certain kinds of NBS. A comprehensive, multidimensional and multi-scale approach focuses on the interdependencies among the various dimensions and scales (Faehnle et al., 2014, Table 3.1). NBS are complex; they rely on ecosystem functioning that evolves and varies in space and time, thus the assessment of their benefits is strongly related to complex thinking that examines dialogic processes and loops, and the fundamental concepts, through which they can be connected (Morin, 2005; Rouleau & Laborit, 1982). The different aspects and considerations for NBS project development in response to the uncertainty and complexity of NBS are examined in Chapter 4.

The dimensions related to NBS impacts can entail various aspects (also called dimensions), such as spatial, temporal, ecological, social, jurisdictional, cultural, or economical. An example of the possible levels of consideration for spatial aspects can be e.g. building, block, district, municipality, region, and an example of the social scale levels could entail individual, family, group, and a larger population. The important scale dimensions and the meaningful levels depend on the focal task. In general, the categorisation of scale levels- such as fine-scale, local and regional scale (used in this chapter)- is a matter of subjective decision and depends on the criteria of categorisation. Regarding NBS, scale levels can be conceptualised according to the specific planning task in any scalar analysis. In the following text in this subchapter, some of the issues, shown in Table 3.1, are thoroughly described.

Table 3.1. Examples of various ecosystem services and other NBS benefits related to relevant NBS types at different scales, inspired by Faehnle et al. (2014)

	ECOSYSTEM SERVICES - BENEFITS	FINE SCALE	LOCAL SCALE	REGIONAL SCALE
PROVISIONING SERVICES	Nutrition and food security	Ground-level and roof gardens, planting boxes, temporary re-use of space for growing food	Allotment gardens, edible forests, food sites (for fishing, mushroom and berry picking), edible greening	Crops, pastures, wild food
	Drinking water and water resources	Permeable vegetated surfaces that increase infiltration	Ponds, streams, shores, reed beds, ground-water protection	Water-shed protection, lakes, oceans, flooding areas
REGULATION & MAINTENANCE	Carbon sequestration	Installing NBS with low carbon footprint, use biochar in substrates	Green areas, trees, management without using fossil fuels	Low-carbon approaches, Protecting and restoring forests, coastal biotopes, peatlands
	Biodiversity including genetic resources	Vegetated roofs, parks, open waters, plants propagated from wild local origin, woodland	Variety of NBS using local declining species propagated from wild origin, open waters	Connectivity, large nature areas, conservation areas, variety of landscapes
	Pollinators for food security and biodiversity	Native flowers from early spring to late autumn, forage plants for larvae, nesting sites (sand, soft wood)	Meadows and parks rich with nectar plants, habitat for species in decline, linear NBS (e.g. transport corridors)	Connectivity, large nature areas, reconfiguration of infrastructure (e.g. streets into greenspace)
	Flood risk control, storm-water management	Permeable vegetated surfaces, green roofs, local green, sustainable drainage	Trees, flood areas, meandering rivers, bogs, mangroves, permeable pavements, green tramways	Watersheds with abundant vegetation and tree cover, large deltas, wetlands and bogs, flood plains

R & M	Erosion control	Using mulch, compost, plant residues as soil cover; planting of seagrass and mangroves	Revegetation of riverbanks, meandering riverbeds, agroforestry	Preservation of forests and vegetation cover
CULTURAL-SOCIAL	Aesthetic improvement	Vegetated roofs and facades, multisensory NBS, restoring waterways in cities	NBS nourishing all senses, local nature, meandering riverbeds	Large connected green infrastructure,
	Cultural heritage	Individual trees, plantings, nature elements; sites with historical, cultural, or identity value	Local vegetation, official heritage sites, valuable sites for recreation and nature appreciation	Nature conservation areas, use of local vegetation in NBS
	Active life style	Easy access to inspiring green space for all (including children, elderly and disabled)	Gradients of challenge, elongated green spaces, connectivity, variation, attractions	NBS for soft mobility - forests, meadows, bogs, parks, and streets transformed into greenways
	Restoration from stress or illness	Quiet lush NBS, views from windows to NBS, easy access	NBS supporting walking and relaxed social activities	Large nature areas
	Knowledge creation, education and awareness raising	Indigenous species, pollinators, variety of NBS, biodiversity elements, long-term research sites	(Semi-)wild nature, open waters, remnant forests, meadows, dead wood, long-term research sites	Large nature areas with little maintenance, natural dynamics, nature conservation areas
	Social cohesion, social capital	Community gardens	Co-management & co-planning of green space	Co-management & co-planning of landscape

ECONOMIC	Touristic development	Diverse NBS based on local species at tourist attractions and hotels	Lush and diverse NBS along major touristic routes	Large destinations with local nature, land-race and wild species
	Increased regional value	Visible vegetated roofs and facades	NBS providing recreational opportunities: open waters, forests, parks	Large preserved nature areas with recreational opportunities
	Other economic benefits	Nature-based tourism	Reduced costs for water treatment	Production of timber, food, plants for NBS

Fine scale
At the fine scale, NBS include, among others: yards, gardens, pocket and neighbourhood parks, vegetated roofs and walls, as well as trees, water elements, and edible plantings (Faehnle et al., 2014; Mesimäki et al., 2017; 2019). In general, the **greening** at this level may contribute to the mitigation of heat islands and noise, supporting biodiversity, reducing the risk of floods from cloudbursts, and decreasing energy consumption in buildings.

Focusing on the **everyday lives of people**, local greening allows easy and equal access to nature, which is a basic equality, well-being and health issue, defining a human right. Prospects for recreation and nature experiences from the window and the doorstep are important. Moreover, near NBS, there should be opportunities for soft mobility, sports, playing, gardening, picnicking, and convivial spending of time.

Presence of nature at the fine scale is likely to improve **neighbourhood satisfaction** too: when people are close to nature, they may benefit from it and spend time outdoors. This can be considered as a significant social component, since it offers opportunities for gathering and socialising, which is likely to encourage social bonds within a neighbourhood. Consequently, nature at this scale contributes to the enhancement of well-being of urban residents (Hadavi et al., 2017) and the development of a feeling of place identity (individual and collective), leading to actions of improving public spaces.

Furthermore, **cultural heritage** is an important dimension of sustainable development, and can be important for place identity. Gardens related to historical heritage, local native and landrace plants, local ordinary wildlife, and even single trees that carry symbolic meaning may be of great value (Faehnle et al., 2014; Folmer et al., 2018).

Local scale

At the local scale, trees, parks, forests and other green spaces alter the local environment by moderating the local climate, improving air quality, protecting wildlife, lowering flood risk, and conserving water. Additionally, a comprehensive amount of **local vegetation** is an efficient strategy to improve health and quality of life in urban areas.

Regarding **water management**, while storm-water management solutions can often be implemented at fine-scale, a watershed scale approach to NBS will be most effective to reduce peak runoff and flooding risk (e.g. Davis & Naumann, 2017) for sustainable urban storm-water management systems. NBS should also target cleaner water resources through reduction of surface runoff and pollutants therein. This is an important criterion for NBS, as it has been shown that the amount of nutrient load from vegetated roofs, for example, can be remarkable (Kuoppamäki & Lehvävirta, 2016).

Also, urban greenspaces with lush vegetation help **cool the local environment** through shade and evapotranspiration. Specifically, they are cooler than the surrounding urban area and alleviate heat island effect in their surroundings. A recent review of the already published studies concluded that parks are by 0.94 K (on average) cooler than the reference urban areas during the daytime (Bowler et al., 2010).

Focusing on the social aspect, accessibility to greenways between destinations, with a variety of attractions, restorative environments, quiet spaces, and aesthetically inspiring multisensory landscapes are important (Faehnle et al., 2014). Escaping from city views and the daily urban hassle is important for **recovery from stress** (Hauru et al., 2012; Korpela & Ylén, 2007). Nature offers affiliation with the world of the senses through the sensations it enables, the feelings it fosters, and the imaginary realms it conjures.

Social cohesion means a sense of community, feelings of trust, friendliness, and shared values and norms. For example, Jennings and Bamkole (2019) reviewed several studies that analysed social interaction, reporting activities and green space qualities supporting it, such as barbecues, meetings, organised activities, and participation in the planning and maintenance of parks, as well as physical properties like side-walks, shaded areas, and easy access to parks. These studies show positive impacts of the amount of green space on social cohesion and, consequently, human health.

Finally, at the local scale, **cultural heritage** could entail traditional human-influenced landscapes, innovative NBS, and valuable nature areas. A good example are urban national parks that often contain a variety of cultural, historical and natural values (Finnish

Ministry of the Environment, 2018)[1]. Furthermore, increased naturalness may have a strong positive impact on the emotional side of place identity (Knez et al., 2018).

Regional scale
As human settlements and infrastructure are constantly changing in size and form, they offer great potential to integrate NBS, where nature can be integrated in various ways. **Urban renaturing** may be a useful approach to radically transform the landscape (Clergeau, 2011). Renaturing refers to a process of spatial transformation resulting from the expansion of nature (flora, fauna, water, soil, microbes, fungi, habitats) and the restoration of ecological functioning in human environments. Renaturing may be an essential ingredient in all NBS projects and should be conducted on a large scale to envision nature as an integral part of human-created landscapes.

According to the recent annual review by the UNDRR (UNISDR, 2015), 87% of the natural disasters in Europe are driven by the negative effects of climatic change in tandem with the **degradation of the natural environment**. Approximately 60% of all ecosystem services and up to 70% of regulating services are degraded or used unsustainably (MEA, 2005). This fact is linked to a number of human activities, such as over-exploitation of resources or higher demand for ecosystem goods than can be sustained (e.g. overfishing), land use and land cover changes (e.g. changes to habitats due to conversion to croplands and urbanisation), invasive alien species, and pollution (e.g. from chemical waste and agricultural inputs). Ecosystem restoration and creation of semi-natural water bodies and hydrographic networks are considered very effective in the prevention and reduction of fluvial and pluvial flooding, coastal flooding, landslides, and drought (e.g. Browder et al., 2019). There are numerous case studies around the world, where NBS have been successfully implemented to address such risks. In most cases, large scale (i.e. beyond the urban boundaries) integrated solutions are more effective for **holistic risk management and resilience**. In several cases, the integration of green and grey systems is considered important for the efficient and successful large-scale implementations. However, it is important to note that investing in ecosystems cannot be a single solution to disasters. NBS should be used in combination with other risk reduction measures, such as early warning systems and disaster preparedness. Ecosystem thresholds may be surpassed depending on the type and intensity of the hazard event and the health status of the ecosystem, which may provide insufficient buffering against hazard impacts. In some cases, combining ecosystem-based approaches with engineered structures (hybrid solutions) may be necessary to protect critical assets especially in densely populated urban areas (Sudmeier-Rieux, 2013).

Preservation of original species is a pressing need, because the rapid dwindling of biodiversity threatens ecosystems and human societies world-wide. However, the need for action

[1] https://www.visitturku.fi/en/turku-national-urban-park

is immediate, as the time window to mitigate the mass extinction is three decades at maximum (Ceballos et al., 2017). Both conservation of what already exists and innovative NBS supporting specific target species are needed everywhere. Natural and semi-natural forests and woodlands, bushlands, meadows, pasture lands, heaths, mires and wetlands, as well as building-integrated greening, offer habitats for declining species that are highly valuable (Beninde et al., 2015).

In Europe, the landscape also changes as the result of modern **agricultural policies and practices**. The trend to create large areas of agricultural land has led to the destruction and fragmentation of the natural ecosystems. Therefore, the goal of NBS is to re-establish the natural biotopes by replanting and re-naturing as well as building corridors between fragmented ecosystems. Furthermore, the widespread use of pesticides and biocides has negative effects for flora and fauna on agricultural lands and NBS should be based on biological control, crop rotation, and agroforestry, avoiding chemical control.

An overall presence of nature (rather than occasional site-limited solutions) means living in an environment with wildlife and such **wild or semi-wild biotope**s as flood-prone areas, meadows, and woodland. In fact, there is a need for envisaging nature and the relationships between humans and natural and building environment. While (re)defining future perspectives, the overall presence of nature also supports regional scale accessibility to well-connected networks of NBS for restoration and positive health and wellbeing effects.

3.2. Benefits versus unwanted impacts

Although the idea is that NBS are by definition sustainable and produce benefits, it is nevertheless possible that careless or ignorant planning and implementation may result in undesirable impacts on-site, due to imbalance in natural resources consumption or the use of harmful materials. Thus, it is always important to extensively explore the knowledge that is richly available in scientific literature and applied sources such as the ThinkNature platform[2].

It is possible to **classify** the benefits and unwanted impacts in many ways, considering environmental, social, economic, or other aspects and the existing porosity among NBS categories (see Chapter 2). For instance, NBS can decrease air pollution (environmental), which allows a decrease of diseases related to air pollution (health), and ultimately the need to cure them leading to public savings (economic). Consequently, the benefits are multiplied and interrelated. Also, systemic thinking, scalar approaches, ecosystem services, and (re)naturing emphasise the multiple roles of NBS and provide conceptual tools for integrated NBS strategies.

The potential for multiple benefits and unwanted impacts means that the effectiveness of every NBS must firstly be assessed during the planning phase, in order to ensure multiple benefits with minimal unwanted impacts (see Chapter 4). For instance, introducing trees in cities is likely to bring benefits such as carbon sequestration and the decrease of heat island effect, but at the same time, it may result in emissions of biogenic volatile organic compounds (Livesley et al., 2016), allergic reactions (Cariñanos et al., 2019), and fire risks (Lehvävirta, 2007). Thus, a thorough analysis according to each local context is needed to select the right species, as well as the spatial arrangement, management procedures, and the appropriate number of trees. There is a strong consensus that the overall impact of NBS potentially outscores grey infrastructure. However, thorough NBS impact evaluation is needed for the comparison of benefits and costs between NBS and grey solutions. In the following text in this subchapter, some issues regarding positive and negative NBS impacts are described (Table 3.2). However, it's worth noting that the benefits and risks mentioned are quite flexible, as every NBS is planned and implemented in a particular context.

[2] https://platform.think-nature.eu/

Table 3.2. Examples of benefits versus possible harmful impacts of NBS.

BENEFITS	LOCAL RISKS	WIDE-SCALE RISKS
Reduction of air pollution	Release of VOC, increased pollution by slowing air flow	Pollution emissions during production and transport
Support biodiversity, offer space for declining species	Damaging biodiversity via transport of exotic species	Homogenised landscapes with one-size-fits-all solutions
Mitigation of urban heat island	Heat retention via prevention of air flow	Increased global warming due to carbon release during production and transport
Preventing and recovering from pluvial flooding	Flood risk not reduced enough due to poor solutions	Exacerbating cloud bursts and sea level rise due to carbon release
Improved landscape and greenspace connectivity	Malfunctioning connectivity for the related organisms	Wide-scale dispersal of unwanted organisms
Noise abatement	Noise from management machinery or unexpected forms of use	Noise from production and transport
Social cohesion and social inclusion	Exclusion due to failure of recognising different user groups' needs	Segregation due to unequal access to NBS
Offer public space and accessibility	Spaces remaining unused	Wasted natural resources
Savings in energy use and costs via cooling	Cooling impact not achieved due to unsuitable plants	Fossil fuels used for material production
Increased value of the space or area	Inequality among different societal groups, space needed for NBS	Gentrification of urban areas

Environmental impacts

In general, all NBS types can have strong positive environmental impacts. However, there are also potential risks if the planning is not informed by scientific evidence because the actual capacity of NBS in environmental improvement is highly vulnerable to lack of knowledge and ignorance.

Regarding **vegetation**, using the wrong kind for the specific case may not provide the cooling impact, or at worst, it may even exacerbate heat instead of cooling (Peng et al., 2019; Solcerova et al., 2017; Vaz Monteiro et al., 2017). Yet another example of unwanted effects is that invasive species and unwanted plant diseases or pests may be spread to new areas along with long-distance transportation of plant materials and substrate (Table 3.2). Furthermore, green roofs with thin substrates and succulents may not be effective in flood risk control, heat reduction or noise abatement. For flood control, a good water retention capacity in the substrate and effective water consumption by plants is important, while for successful noise abatement, the actual design and management of vegetation play a major role (Connelly & Hodgson, 2013; van Renterghem, 2014). In the case of reduction of air pollution, choosing tree species, not producing VOC and allergens but adsorbing and absorbing a maximum amount of air pollutants, is important. However, the positioning of the trees needs to be considered in order to make sure pollution is not captured and retained in places of frequent visits by humans (Ghasemian et al., 2017; Yli-Pelkonen et al., 2017). Furthermore, transport during construction as well as emissions due to maintenance need to be considered, in addition to other kinds of possible unwanted impacts (gentrification, noise, forms of use, etc.).

For **biodiversity**, the type and number of species used in NBS will determine the impact. Theoretically, NBS provide ample opportunity for biodiversity protection, as a wide variety of NBS are constantly built and maintained globally. However, ignorant implementations may result in unwanted impacts. Basic knowledge, about how to support declining species efficiently is still lacking among NBS practitioners, and full advantage of scientific literature - which gives sufficient guidelines to support biodiversity - is not taken. According to up-to-date relevant literature, NBS should be based on indigenous species in a broad geographic sense, taking into account climate change scenarios and plant provenances. In a warming scenario, this may equate to species derived from warmer conditions, but as close to the location of NBS as possible, from where the species would be migrating. NBS could take advantage of the idea of assisted migration in order to protect species threatened by climate change (Hällfors et al., 2014), by providing new and suitable habitats for plant and animal populations suffering from climate change.

Worldwide, natural ecosystems, especially forests, peat bogs, and oceans, act as carbon sinks (Table 3.3). However, as for man-made NBS, the net CO^2 balance depends on the production, use, and end-of-life phases (e.g. Bozorg Chenani et al., 2015). Specifically, although there are promising estimates about the capacity of several types of NBS to sequester carbon and to help avoid carbon emissions (Getter et al., 2009; Mohareb & Kennedy, 2012; Whittinghill et al., 2014), intensive management based on fossil fuels significantly reduce the net carbon balance.

Last but not least, it is essential to notice that although there is a high consensus about the significance of NBS in addressing major global environmental and societal challenges (see Chapter 1), it would be short-sighted to think that NBS could be the only means to reach such objectives and goals (e.g. SDG). NBS can act in combination with several other regulations, actions, and tools in multiple levels to reach sustainability. The main emphasis is given on the actual root causes (i.e. focus on the reasons and curing of the illness rather than mitigating the symptoms), where appropriate local, regional, and global scale regulations and actions would help change the current situation. For example, climate change needs to be tackled by drastically reducing and stabilising the atmospheric greenhouse gases in the first place (Ballantyne et al., 2018), and biodiversity needs to be protected by regulating the human activities and land uses putting it at risk.

Table 3.3. Typical rates of carbon sequestration, i.e. the rate of carbon uptake in various biotopes.

BIOTOPE	RANGE OF CARBON SEQUESTRATION (tC/ha/yr)
Wild grassland	0.35 - 0.7 (Conant et al., 2001)
Seagrass	1.0 – 1.8 (Murray et al., 2011)
Saltmarsh	2.0 – 2.7 “
Mangroves in estuary	2.0 – 3.0 “
Oceanic mangroves	3.0 – 6.0 “
Tropical forest	1.5 – 2.0 “
Boreal forest	1.0 – 1.5 “
Urban forest	2.9 (Mohareb & Kennedy, 2012)

Societal impacts

The presence of nature in cities is likely to result in social, wellbeing, and health benefits for urban dwellers in different ways. With regard to **human health**, Aerts et al. (2018) list a wide variety of evidence-based impacts. Short-term nature visits provide stress reduction, mood improvement, amelioration of depressive symptoms, and improvement of experienced health, while living in close contact with nature reduces, among others, chances of getting cancer, vascular mortality, obesity, and type 2 diabetes. Furthermore, biodiversity can boost our immune systems and help avoid allergic symptoms. However, plants also release unwanted compounds (VOC, allergens) and can be poisonous. Moreover, NBS can provide habitats for species that are detrimental for human health. Therefore, exact knowledge is needed for the planning of NBS.

Additionally, NBS provide **recreation** opportunities for workers, residents, school children, the elderly, and people suffering from mental or physical disorders (Veloso & Loureiro, 2017). Focusing on children, natural places and green elements are a great source of game and entertainment. Some studies underline that playgrounds with natural elements are preferred over other kinds of playgrounds. Also, natural areas, such as forests, are satisfying for children's games and foster imagination and social relations. Consequently, a designed playground and its infrastructure are not sufficient by themselves; the surroundings, especially the proximity to nature, are of high importance for the children's satisfaction and development (Jansson, 2013). In city planning, one way for NBS-friendly policies is to consider the whole city as a recreational area. This means that recreational spaces or areas should not be seen as separate from other areas and high connectivity should be achieved by providing greenways, longitudinal greenspace, and allowing uninterrupted soft mobility. Despite encouraging recreational use and mobility through green space, some NBS may be vulnerable to intensive recreational use. For example, if meadows, forests, and shorelines are fully accessible and lack sufficient infrastructures (such as pathways, duckboards, and guiding), the impact of human activities can be detrimental.

NBS are a way to foster proximity to nature and to reinvent urban places including more natural elements. This may contribute to redefining urban areas and the human/nature relation (Younès, 2008). One way towards achieving it is to allow a strong **involvement of residents, recreationists, workers, and other local stakeholders in NBS projects**. For instance, the Room for the Waal project[3], which aimed to prevent flood risk in the city of Nijmegen and its surroundings, included citizens in the process. The project aimed to have a direct impact on some inhabitants, who lived in the area of the riverbed reorganisation. To make the project acceptable, discussions are needed, allowing the citizens to share their views in a participatory process. Although NBS are likely to improve the

[3] http://www.ruimtevoordewaal.nl/en/room-for-the-river-waal

quality of an area, many variables should be taken into consideration in order to achieve social benefits. For example, there is the potential of gentrification after having enhanced a neighbourhood's attractiveness (Wolch et al., 2014). Urban parks are vital public spaces, where city dwellers of all cultures and classes can coexist. However, the opposite could happen, if the design of the parks fails to provide hospitable places for all different groups of people (Low, 2015).

Another key type of societal impacts is related to culture, as cultural heritage is a key component of landscapes. In general, there are many case studies, in which NBS take into account and are inspired by **cultural heritage**. The strong connection of culture and public policies regarding regional development, social cohesion, agriculture, shipping, environment, tourism, education, digital agenda, research and innovation is undeniable. Such policies have direct or indirect impacts on cultural heritage, while cultural heritage offers great opportunities to achieve the goals of the policies. In fact, the interaction between the pillars of economy, society, environment, and culture lead to a new form of sustainable development, that supports the cohesion of society, economic development, and environmental protection (Giraud-Labalte et al., 2015). The overall challenge is to go far beyond simple conservation, restoration, physical rehabilitation, or repurposing of a site and to demonstrate heritage potential as a powerful economic, social, and environmental catalyst for regeneration, sustainable development, economic growth, and improvement of people's wellbeing and living environments. It is all about learning from the past to design for the future. Preserving cultural heritage, while undergoing cultural changes and matching NBS with both the heritage and the change, could be tested in NBS living laboratories together with citizens (Juujärvi & Lund, 2016; Korpilo et al., 2017; 2018; Veeckman & van der Graaf, 2015).

3.3. Model cases

The indicative cases, described in this subchapter, were selected in order to highlight the multiple and multi-scale benefits of NBS that can be achieved at different levels, types and combinations of NBS interventions.

The case of Berlin: sustainable multi-benefit projects

Figure 3.1. Public space in Berlin (https://oppla.eu/casestudy/19454)

Berlin is a growing urban area and one of the main challenges it faces today is the decoupling of the city's growth from the negative impacts on climate change and the environment. Urban areas are expected to provide sufficient economic and social infrastructure, as well as a high-quality urban environment for all the people living there. As for NBS, it can be said that there are policy drivers helping their implementation, as Berlin has a long tradition of greening its urban areas and has developed a strong frame through strategic planning documents (Kabisch, 2015). Specifically, the Berlin Program for Sustainable Development (BENE)[4] gathers several projects and initiatives in the period of 2015-2020.

Multiple benefits: BENE is by essence meant to be multifunctional, as it is supposed to bring multiple benefits to the city, considering social, environmental, and economic issues. This programme is

[4] http://www.berlin.de/senuvk/umwelt/foerderprogramme/bene/

indeed vast and deals with reduction of CO^2, energy savings in buildings, public transport, but also the reduction of noise and air pollution, the enhancement of the quality of life in urban areas, and other positive (in)direct impacts. One example of a project with multiple benefits is "Ein Garten für die ScherenberstraBe" (Figure 3.1), which is part of the BENE programme, and aims to provide an ecologically effective area (thus fostering biodiversity), while at the same time meeting the safety requirements of a day care garden. The valorisation of the garden allows multiple benefits on the environmental and social sides.

London: NBS for a leading sustainable city

Figure 3.2. Green roof in London (https://oppla.eu/casestudy/19456)

London is a notable case study under classification Type 3 "Design and management of new ecosystems" in the categories of "Intensive urban green space management" and "Restoration and creation of semi-natural water bodies and hydrographic networks". London has planned and implemented a number of NBS to address multiple climate- and urbanisation-related challenges. These include green roofs (Figure 3.2) and walls, planting street trees, expanding or improving green spaces, urban agriculture, natural water retention measures, and the recycling of derelict areas, brownfields, and other urban land.

Multiple benefits: The multiple objectives, set for London NBS, aim at reaching the sustainability goals, while transforming the city into a green capital. Among the multiple benefits, mitigation of surface water flooding, improved air quality, urban cooling, walking and cycling opportunities, aesthetic improvements, and enhancing biodiversity and ecological resilience are included (Mayor of London et al., 2016). In this case, NBS do not only enhance biodiversity and sustainability, but also contribute to climate mitigation through carbon storage, as well as reducing heat stress and flood risks.

Lastly, the case of London proves that multiple benefits can also be achieved when restoring brownfield sites or constructing green roofs.

Delft: Sand Engine

The sand engine on the Dutch coast (Figure 3.3) is a distinct case study for the classification type of "Type 3 – Design and management of new ecosystems", in the category of "Ecological restoration of degraded coastal and marine ecosystems". The sand engine is an innovative coastal management practice that was planned and implemented in order to prevent the erosion of a section of the Dutch coastline, exploiting the stream of the local maritime currents.

Multiple benefits: In the context of restoring the local ecosystem, the sand engine enhances and offers better protection to biodiversity (i.e. local species), securing local habitat and food provision. Additionally, it promotes the sustainable development of the coastal area, while ensuring climate adaptation, risk management, and resilience. The project is designed in such a way that it generates additional benefits for nature development, recreation, and knowledge development (societal benefits) too.

Figure 3.3. Sand engine on the Dutch coast (https://oppla.eu/casestudy/17630)

Helsinki Jätkäsaari: Greenest of the green blocks of flats

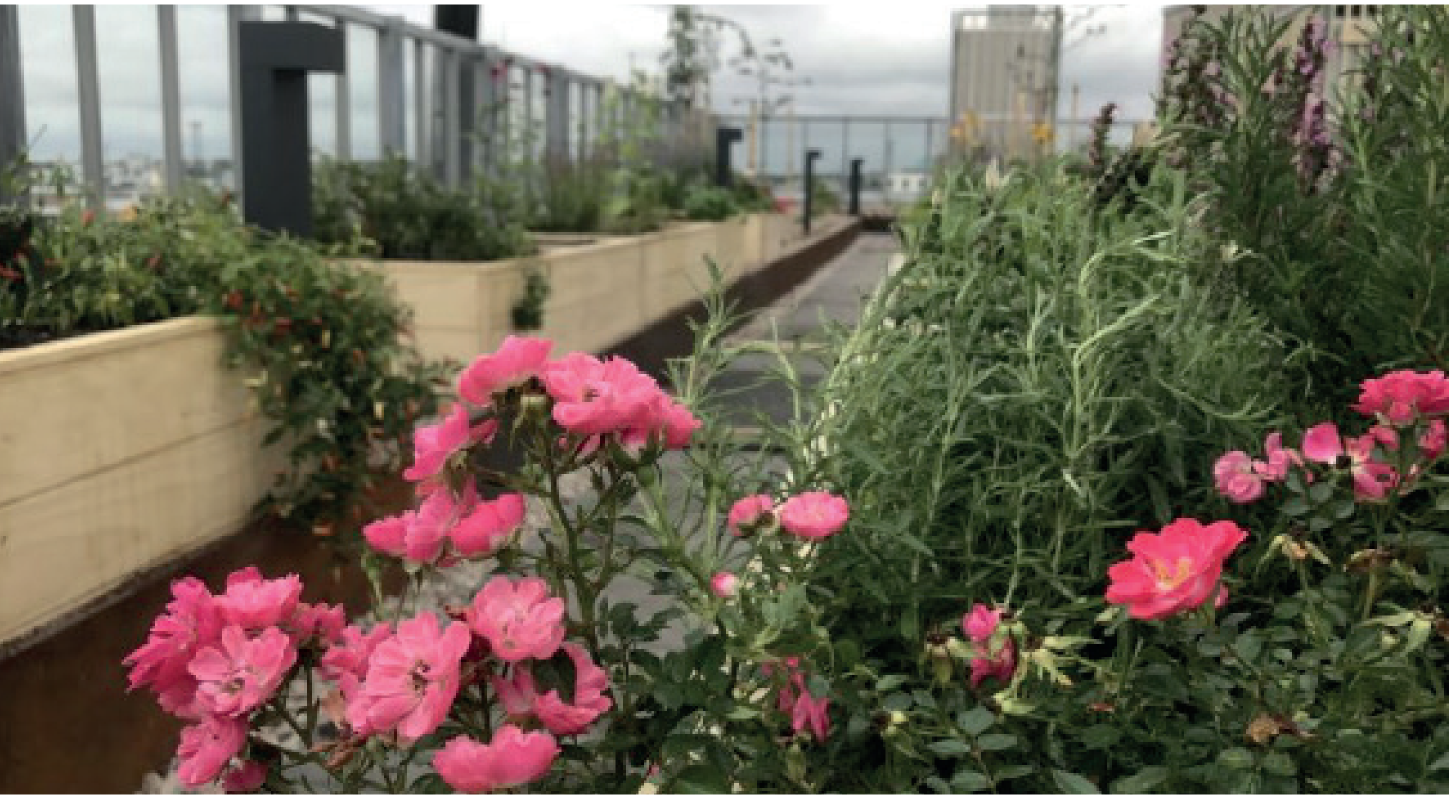

Figure 3.4. Kitchen garden in Helsinki (https://oppla.eu/casestudy/18875)

This block of flats won the Scandinavian Green Roof award in 2018. The planning phase involved multiple professionals, including the investor, architects, scientists, and practitioners. The future perspective was represented with using the results of a survey that collected visions of Helsinki residents regarding green roofs, which revealed desirable uses, experiential qualities, physical properties and social aspects (Mesimäki et al., 2017). The vegetation consists mainly of local native species or traditional cultivars, with no invasive species allowed in the greening. The plants grow surprisingly well despite the harsh conditions of the northern climate that is further exacerbated due to the proximity to sea (Figure 3.4).

Multiple benefits: The main focus of this residential block-of-flats was to support biodiversity and well-being of urbanites through opportunities for recreation, social activity, and growing food (TA-Yhtiöt, 2017)[5]. Also, cooling, building protection, creation of social capital, knowledge creation, as well as on-site storm-water management, are additional benefits of the building-integrated greening that includes vegetated roofs in four different floor levels and greening of three facades.

[5] https://platform.think-nature.eu/nbs-case-study/18875

CHAPTER 4

MAKING IT HAPPEN: PROJECT DEVELOPMENT

4 MAKING IT HAPPEN: PROJECT DEVELOPMENT

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Projects built in the natural environment always face an element of uncertainty. Nature is not fully predictable and the result of a project may necessitate the adjustments over the course of time. This chapter reviews the various steps leading to successful nature-based projects. In the realisation of any project, one can distinguish three successive stages which are: plan, build, operate. However, in the nature-based projects there are elements of uncertainty that necessitate a more detailed planning process. Therefore, a slightly modified terminology is used in this chapter, i.e. Plan, Execute, Deliver (see also Annex 3):

Planning stage: define project goals, specify the strategy and the design approach.
Execution stage: develop detailed design, build/construct, implement.
Delivery stage: operate, maintain, monitor, follow-up.

The implementation of a nature-based project follows these three stages, but the successive steps allow for several iterative cycles. This is necessary because of the uncertainty and complexity:

- NBS in general, and urban NBS in particular, need to involve a variety of stakeholders to create broad support.
- NBS are often proposed to solve a particular problem, but at the same time, they offer multiple ecosystem services. Such complexity makes a project more interesting, but an element of uncertainty is also expected.
- Usually, there is more than one type of NBS conceivable, and selection and design optimisation is necessary.

- Furthermore, nature has its own dynamics and the performance of an NBS is expected to change over time; uncertainty in the results is inherent in NBS and therefore monitoring and feedback is essential.

These differences between traditional projects and nature-based projects suggest that the steps in the design and implementation process should be more articulate. While there are incentives to favour NBS over grey projects, it is necessary to demonstrate their effectiveness. During the design process and the development of the business case, at various stages of the process, the NBS under consideration needs to be assessed in order to optimise the choices and justify the costs. Once the NBS has been implemented, the evolution and functioning needs to be monitored. This requires the definition of clear design goals and the selection of robust monitoring methodologies that are capable of demonstrating the results of an NBS and comparing these to the goals established for the project. Objective methodologies are needed to demonstrate the long-term effectiveness of NBS. Adaptive management is an inherent feature of nature-based projects. Adaptive management differs from traditional management approaches in that it allows management activities to proceed despite some uncertainty about meeting design goals. In fact, it specifically targets such uncertainty: it compels ecosystem managers to be open and explicit regarding what is known and not known about the processes. It provides a science-based learning process, characterised by using outcomes for evaluation and adjustment ("closing the loop"). In order to do justice to the specific aspects of NBS, the project planning, execution, and delivery stages are detailed in 11 steps as shown in Figure 4.1. These steps are discussed in this chapter.

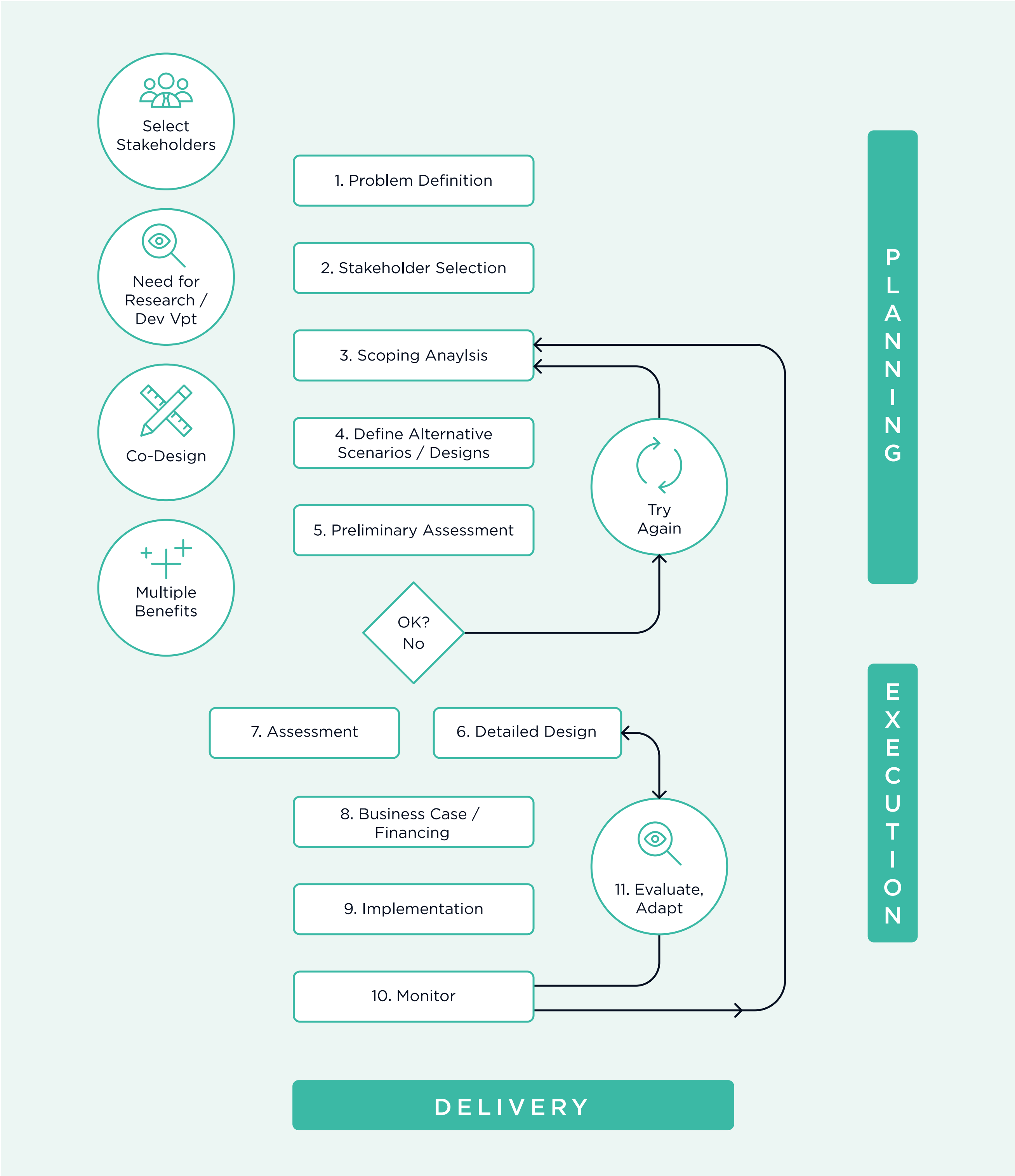


Figure 4.1. Implementation logic for NBS

4.1. Planning stage

Step 1. Problem definition

• What are the challenges for which a solution is necessary?

NBS may form an adequate response to a wide variety of problems and issues. NBS consider climate change adaptation and mitigation issues as well as risk management and resilience. Moreover, NBS serve as a potentially valuable tool for reaching multiple Sustainable Development Goals (SDG) and related sustainability objectives such as the sustainable urbanisation and the restoration of degraded ecosystems. The major hazards to be addressed by NBS include extremes in temperature and precipitation due to climate change, loss of biodiversity, sea level rise, followed by population pressures. These hazards result in many different challenges: heat islands in cities, need for sustainable water management, wide-spread air pollution, risk of flooding, etc. NBS approaches and benefits come in many forms and function at different scales, as described in Chapter 3.

In terms of scale, one needs to distinguish between challenges for the urban environment, in the landscape, for the river catchment, and along coastal zones (see Chapter 2). Within the urban setting, a further breakdown into building scale, urban zones, and cityscape appears necessary. The scale plays a role in defining the specific problem that can be addressed at this level of scale. Risk of river flooding needs to be addressed at the catchment scale, pluvial flooding requires responses at the scale of an urban zone, combatting heat island effects is best done at the scale of an entire city. Issues that can be addressed at the scale of buildings or streets would include improvement of the environment by more nature (gardens, roof gardens), water management at building scale, development of 'commons' to promote social cohesion.

It takes a project sponsor to trigger the definition of a problem and to suggest further action. Project sponsors can be authorities at all levels, local citizen initiatives, NGO, but also commercial developers. This stage of project development should result in an outline of the problem and possible approaches (resources, timeline, legislative restrictions, etc.).

Step 2. Stakeholder selection

• Identify all stakeholders and get them involved.

Identify all important stakeholders, i.e. all actors in the planning, implementation, and maintenance phases, as well as the end-users. This involves the parties directly involved in the planning and implementation process, but also third parties affected by the project. Every planning process should start with a screening of people who may have an interest in the functionality of the nature-based solution. A successful NBS builds on the input of experts from different disciplines and scientific domains. Ecological and other natural scientists should be invited to offer innovative NBS. At the same time, engineering scientists should contribute to the design and testing of innovative NBS. And finally, social and economic scientists should be involved in order to facilitate and support uptake of NBS by stakeholders.

Stakeholders to be involved in the planning process of an NBS could include: politicians, public agencies, scientists, institutions, experts, communities, Non-Governmental Organisations, land owners and developers, firms, etc. (Somarakis et al., 2019).

Everyone who has responsibility in the planning of the structural, architectural, and technical aspects at the site where the NBS is foreseen should take part in the planning process. Clearly, the group of stakeholders will be very different and more structured in the case of a multimillion coastal protection project than for the creation of a nature-friendly playground. The representative stakeholders should be involved early on and contribute in particular during the preliminary design stage.

The plan to develop an NBS in response to a particular challenge may face resistance for reasons of unfamiliarity, established interests, or traditional values. There are, however, several ways to manage such issues. For example, investors can be forced to create a wide collaboration via green procurement rules. Another possibility is to motivate via information sharing, strong communication skills, or by reference to visionary examples and pilot projects. It may be necessary to introduce new expertise covering, for example, ecology, hydrology, psychology!

Finally, it is important to include everyone early on. Just one example: if a structural engineer is not included in the planning of a vegetated roof from the beginning, it may only be noticed too late in the process that the support structures are too weak, which may ruin the aims for rain water retention.

Step 3. Scoping analysis

- **Goal definition: Specifying the problem and its framework (resources, timeline, legislative restrictions, etc.) as well as the purpose for conducting this process.**

Document the problems that the NBS should solve, the challenges it should meet, and the aims it should fulfil. Realistic estimates should be developed for the resources that can be mobilised, the time frame, the expertise required, and the need for expert support. The legislative framework must be clarified: are permits required? Is there a need for public procurement? Are there specific norms or standards that apply?

The idea of NBS is that different aims can be targeted simultaneously, and to do this, a thorough mapping of the expected benefits needs to be carried out as well as possible drawbacks. The ecosystem characterisation, including the specification of its boundaries, its future development, and an inventory of possible ecosystem services should be clarified. NBS may play an essential role in the local community and the stakeholders need to be consulted at this stage on the socio-economic aspects. The link between ecological systems and societal systems should be efficiently established. Therefore, it is important to be inclusive while defining the targets, and to enhance communication so that everyone in the process has a chance to reflect on the issues.

Examples of the methods that could be used to map the wanted benefits from the NBS include the method of empathy-based stories (MEBS) and walk-and-talk meetings in existing environments; these should reflect essential aspects of the planned NBS. Note that these are only examples of the toolkit of techniques to stimulate interaction. The consultation of a broad range of stakeholders and knowledgeable actors should allow for a multidisciplinary approach. At this stage, a need for further research or development is identified as well. Where novel approaches are envisaged, it may be recommended that a pilot project should be developed to test the assumptions and/or scientific evidence.

In summary, objective performance criteria must be defined at this stage; they will enable the assessment and monitoring of the functioning of the NBS, once implemented. These criteria should cover the expected ecological, environmental, social, and economic outcomes of the project. Ideally, this phase should result in the specification of the goals, the constraints, and the design requirements.

Step 4. Multiple scenarios

- **Scenario development: Structuring a set of preliminary designs or scenarios based on system analysis.**

The project can now proceed with the development of a number of alternative preliminary designs or scenarios. For simple NBS, the entire team of stakeholders can be involved; for more complex infrastructure NBS, a team of experts should outline the alternatives. A highly motivated team will likely perform well. Since NBS is still breaking new ground, the team needs to build trust and operate with a high degree of transparency. The use of multiple planning and assessment tools is useful for visualising possible impacts and benefits of the NBS. There are various innovative datasets and tools available nowadays for achieving holistic scenario building. Some of them are referred to in Chapter 5.

Knowledge could be shared in information sessions where scientists and other stakeholders experienced in NBS present recent innovations related to the targeted NBS. For example, it is important to recognise and discuss the dynamic nature of biotic systems: an ecosystem is continuously changing, responding to external disturbances, adapting to changing conditions, and interacting with its surrounding environment. The dynamic nature of ecosystems may change the benefits over the lifetime of the NBS. Ideally, NBS should function with minimal maintenance, and therefore it is important to recognise that the appearance and functionality of a solution evolves. It is also important to evaluate the different materials and construction techniques in terms of their sustainability and resource consumption during and after the building phase.

To illustrate the process with a complex example: a coastal defence system consists of several elements. They function together as a system to resist the threats of wave attacks, erosion, flooding, storm surges. Different scenarios for building natural defences are conceivable: strengthen barriers against wave attack, reduce erosion by limiting longshore drift, create higher barriers against flooding, or combinations of these. The selection of an optimal nature-based solution can only be made after in-depth analysis based on models of local wave climate, hydro-morphology, sediment transport, sediment supply etc.

Step 5 – Preliminary assessment

- **List the multiple benefits and drawbacks that may be expected for each design/scenario.**
- **Scenario assessment: Evaluate the preliminary designs or scenarios by using multiple performance criteria defined in step 3 and select the preferred approach.**

Note that in the case of NBS there are two phases in the design process: the preliminary design and the detailed design. This also necessitates two corresponding stages in the assessment. In this step, the preliminary designs must be assessed in order to select the most promising solution.

Data development

The idea with NBS is that different aims can be targeted simultaneously, and to do this, a thorough mapping of the expected benefits and constraints needs to be carried out. As NBS are new for many people, the benefits that NBS provide are not generally understood by all stakeholders; positive interaction must be stimulated. All the stakeholders should be involved in listing the multiple benefits that may be expected from each alternative design. The benefits should preferably be categorised as environmental, social, or economic. At this stage, the possible disservices and constraints for each alternative should also be compared. An example of the representation of the multiple benefits of NBS is shown in Table 4.1. The example applies to the case of coastal mangrove restoration. This representation can be used for the preliminary assessment of any proposed nature-based project.

Table 4.1. Multiple benefits from coastal protection by restored mangrove forest

MAIN ISSUE: RESTORE COASTAL DEFENCES	BENEFITS/ECOSYSTEM SERVICES
Environmental/ecological	Erosion protection, barrier against saline intrusion, enhance biodiversity, carbon sequestration, water purification
Economic	Fish nursery, seafood production, honey production, construction material, substances for medicines, reduced flooding risk
Social	Support local community (‘commons’), bird watching, tourism

It is necessary to not only identify the expected benefits, but also to list the possible negative impacts as completely as possible (‘disservices’). Tables 3.1. and 3.2. (Chapter 3) can be used to help the stakeholder groups focus on the essential questions:

What are the scalar impacts of the project? What would the positive outcomes be? Are there possible benefits beyond the scale of the project? Can the benefits be quantified? Are there metrics available to assess the benefits? What would key indicators for success? Who will actually be advantaged by the benefits resulting from the project: the project owners, the neighbourhood, the property developers, or others? It may well be that some benefits are of advantage to third parties that could in turn be approached to contribute financially to the project!

Preliminary costing data need to be collected as well. The various alternatives need to consider cost impact over the life-cycle, but the detailed cost figures are developed in step 7.

Methodology
In this stage, one or more of the following methods may be used as basis for the preliminary assessment and selection.

Multi-criteria assessment (MCA)
An MCA is a semi-quantitative analysis in which the performance of a number of measures is scored against multiple criteria. The scoring should be based on expert/stakeholder opinions. The criteria may be chosen in view of the problem at hand. In any case, environmental, social, and

economic aspects should be scored, for example, on a scale of 1 to 5. The various criteria may have different weight, but it is usually possible to select a preferred solution. The technique is very useful for consulting multiple stakeholders involved in the assessment. An example of an elaborate MCA is included in Section 4.4.

Cost Effectiveness Analysis (CEA)

The CEA method can be used if the NBS primarily targets a single issue such as flood protection, combatting noise pollution, or extreme climate effects. The comparison is also done on the basis of expert judgement. The cost estimates for each alternative should cover preliminary operational and maintenance costs. The assessment should answer the question: how much protection would each alternative provide for a fixed amount of investment? ("How much flood protection per euro?"). A drawback is that the method does not give credit to multiple benefits and other services provided.

Life Cycle Costing (LCC)

In LCC, the costs over the entire lifetime, (investment, operation and maintenance and if relevant, demolition costs) are compared over a fixed (long) term horizon. In theory the alternative with the lowest LCC is the most attractive. This method focuses on the financial and monetary aspect and also has some drawbacks: it is rather cumbersome to estimate the costs upfront with sufficient precision, and the non-monetary aspects (benefits) that often drive an NBS may be underestimated. Furthermore, discounting costs that will be incurred in a distant future is always risky, as the selected discount rate dominates the results.

In conclusion, the most promising method for choosing between a series of alternative design concepts or scenario's is usually the multi-criteria assessment.

INTERIM: GO / NO-GO?

Following the preliminary assessment, an important decision must be made:

- [ ] Is the preferred alternative fit to meet all the requirements and constraints?
- [ ] Is it the basis for detailed design and implementation?

If the answer is 'no', the development of scenarios and alternative designs should be revisited. In the field of nature-based approaches it is typical to go through one or more iterative cycles to optimise the NBS and maximise the benefits.

4.2. Execution stage

Step 6 – Detailed Design

• Once the preferred preliminary design has been selected, the detailed design is developed.

It very much depends on the type of NBS as to how much detail is necessary in the design. For the development of allotment gardens, the design work is limited; the applicable rules for the development should be specified. On the other hand, a project to reconnect the floodplains in a river basin needs detailed design and may be composed of a 'toolbox' of different techniques that are applied along the river catchment.

Step 7. Assessment

• A more detailed assessment of the environmental and financial aspect needs to be carried out.

For simple NBS projects with few financial constraints, the assessment in step 5 may be sufficient. But for complex and large-scale projects, the questions of permits and financing need to be dealt with. If detailed assessment is required, this effort can be developed in parallel with the detailed design step (step 6). The first item to address at this stage is the question of whether or not a special permit or licence application needs to be prepared. Depending on the scale of the project, two formal analyses may be required:

Environmental Impact Assessment (EIA)
The EIA is a rather formal analysis of the environmental benefits and impacts of large infrastructure projects. Its use is mainly intended for grey infrastructure projects, but large NBS projects may fall into the category where an EIA is obligatory. In the European Union, EIA is a procedure to ensure that the environmental implications of projects are considered before final decisions are made. Environmental assessment can be undertaken for individual projects, such as a dam, motorway, airport, or factory, on the basis of *Directive 2011/92/EU* (known as 'Environmental Impact Assessment' – EIA Directive; EC, 2011) or for public plans or programmes on the basis of *Directive 2001/42/EC* (known as 'Strategic Environmental Assessment' – SEA Directive; EC, 2001). The word 'impact' usually has a negative connotation, but in the case of NBS projects the positive ecological and environmental aspects need to be highlighted. The EIA report constitutes the formal application for a construction permit.

Cost-benefit analysis (CBA)
For NBS projects that require financing by third parties, a formal CBA may be necessary. In a CBA, the costs of the project are compared to the welfare effects/benefits/negative impact. If the value of the benefits exceeds the costs, the project is in principle feasible. For NBS projects that are financed by private capital, a comparison with alternative solutions is desirable. The cost/benefit assessment may be determined in relation

to a reference situation ("do nothing") or to an alternative 'grey' project with similar goals. At this stage the most realistic estimates of the costs must be developed, and it will be necessary to update the numbers for *life-cycle costing* as developed in the preliminary assessment. If comparison with a grey project is envisaged, similar life-cycle costs should be developed for both cases. This is an important consideration for NBS, since many commercial projects tend to consider only initial investment costs, rather than life-cycle costs.

To the extent that it's possible, impacts and benefits are valued in monetary terms to ensure comparability. For NBS projects it is very important to assess a complete range of benefits: environmental, social, and economic. There is still much discussion on whether or not all environmental and social benefits ('ecosystem services') should be expressed in monetary terms (e.g. Schröter et al., 2014). When expressing all the benefits in monetary terms, a rather subjective element in the assessment may be introduced. Therefore, where possible, only qualitative criteria and expert judgement should be used to assess non-economic aspects.

It is also very important to include an *estimate of avoided damage costs* in the comparison, for example for NBS that deal with hazard mitigation. The advantages of NBS can in many cases be established on the basis of monetary value of the economic benefits only, while it suffices to spell out the environmental and social benefits only qualitatively.

When considering the costs and benefits produced over the life cycle, there are other methodological issues: the costs and benefits are not all realised at the same time. An estimate of the timing in delivering benefits and charging costs is necessary to allow for proper discounting effects. This question is particularly relevant for calculating the value of avoided damage costs (when, how much, indirect costs of damage as well?).

Step 8: Business case / Financing

- **Public versus private**
- **Sources of finance.**

Based on of the assessment and economic analysis outlined in step 7, a detailed business case needs to be developed. Beyond the question of costs, other issues arise:

- Is the project in the public or private domain? If public, is a public procurement process necessary? If private, can finance be found?
- Who will benefit from the NBS? The project owner or third parties as well? If third parties benefit as well, are they willing to pay for the benefits received? In that case the project owner needs to invest in the project, but may reduce the financial burden in the operational stage.
- Is public-private partnership an option?
- What other resources are required to realise the project?

More details on developing the business case are provided in Chapter 6.

Step 9: Implementation

This step covers the building/construction/realisation of the detailed design. The details (schedule, project management, resources, etc.) depend very much on the scale, the type of NBS, and the location of the project.

4.3. Delivery stage

Step 10: Monitoring

Once the NBS has been implemented, the proper functioning and evolution needs to be monitored. This requires the selection and design of robust monitoring methodologies that are capable of assessing key performance indicators. The selection of the appropriate monitoring methodologies for each NBS project depends on various factors, notably performance goals, the NBS type, the scale of implementation, the expected impacts and benefits, and the available resources for monitoring. However, there are some critical methodology requirements that apply for most NBS cases.

Long-term and variable scale monitoring
The scale of NBS and the scale of the NBS impacts in both space and time must be adequately addressed by the monitoring methodologies. NBS impacts vary from micro (e.g. street level), to meso (e.g. city level), and macro scales (regional to national level). Moreover, NBS are based on dynamic ecosystem processes that evolve over time. The functioning of an NBS may therefore be affected by the changing climate. In some cases, the NBS may only unfold its full benefits over a long period of time.

Availability of baseline data
NBS performance is ideally evaluated by comparing the status prior to and after the implementation. Baseline data represent the pre-NBS situation and should be available in an adequate format, quality, and quantity to support the comparison with the post-NBS situation. Longer past time-series of data are sometimes needed for the complete evaluation of environmental effects (e.g. urban temperature reduction, erosion effects).

Feasibility – comparability - replicability
The ideal monitoring methodologies are the ones that would need the minimum of specialised equipment and effort, so that it becomes feasible to implement similar methods across several case studies or projects. The data used should be able to be standardized and replicated under different areas, conditions and scales. For large-scale green infrastructure, aerial or satellite remote sensing is a favourable option.

Quality and accuracy
The methodologies used must be of the highest scientific quality, taking into account the whole range of physical processes and interactions associated with the monitored parameters. They should be widely accepted by the scientific community and approved by the experts of the related fields. Moreover, the data and methods should have already been validated and ideally should always report the accuracy of the output measures.

Cost effectiveness
A critical parameter for the adoption of specific monitoring methodologies on NBS implementation is the cost associated with the implementation of the monitoring techniques. There is a need to develop simple and cost-effective solutions for the efficient monitoring of NBS, simultaneously considering all the above criteria.

Step 11: Evaluation / Adaptation

The results of the monitoring will be compared to the design goals and performance criteria. The evaluation provides evidence as to whether or not the NBS functions and operates as expected.

As nature-based projects are typically based on the functioning of dynamic ecosystems, with all the uncertainty that this implies, it is likely that the design objectives are not completely achieved. In that case, the feedback information may be used to revisit scoping analysis (step 3) or the detailed design (step 6) in an iterative cycle and to check if adjustments are necessary or possible, in order to meet the principal NBS objectives.

This iteration is a form of adaptive management. The goal is to adjust the performance and evolution of dynamic ecosystems to meet the specifications and objectives (Nesshöver et al., 2016).

A few examples:

- For an urban drainage scheme, it could be found that the capacity is insufficient to cope with torrential rains and thus the water absorption capacity needs to be increased.
- For a constructed wetland, the criteria are that the discharge water meets a certain quality standard. If this standard is not met, the choice of vegetation may be adjusted, or the flow-through period could be prolonged.
- In a coastal protection scheme, the supply of sediment may be insufficient; other techniques to activate sediment resources may have to be pursued.

4.4. Practical considerations

The various steps in the design and implementation process of a nature-based project are more complex than in traditional projects. This is the consequence of the complexity and uncertainty associated with the functioning of natural systems:

- NBS deal with more uncertainty than traditional ('grey') projects because the evolution of ecosystems by definition carries uncertainty.
- NBS form a response to external events that equally evolve under uncertainty.
- As both the NBS and the external threats will evolve, NBS function in a dynamic and highly complex context.
- NBS usually feature a variety of benefits in the form of ecosystem services, but some of which are only indirectly related to the goals of the project.
- NBS should be supported by a wide range of stakeholders that need to be consulted on the goals and the realisation of the project. This requires an open and transparent design process.
- Life-cycle costs need to be considered in order to develop a fair business case. This affects the complexity of the assessment.

Feedback and iteration are decisive characteristics that distinguish NBS logic and decision making from projects using grey elements or grey infrastructure.

The management of uncertainty is necessary, and this should be done through adaptive management via several feedback loops: one or more in the definition stage, where the choice between several alternatives must be made in the face of uncertainty. A second feedback loop builds on the data from monitoring during the delivery (operational) stage and serves to adjust the system performance in line with the design goals (adaptive management). A third feedback loop re-connects the effects to the initial scenario development: this iteration is necessary in the case where the goals of the NBS project have not been achieved at all.

The need for iteration and feedback has been highlighted in past and ongoing projects studying NBS. The Openness project[1] defined a multi-criteria assessment process (Catrinu-Renström et al., 2013) for NBS project development where the need for continuous feedback of information in the design stage was highlighted. It is argued that a sound multi-criteria design analysis of NBS scenarios may be needed to develop all the steps in an iterative manner in order to arrive at the selection of the optimal preliminary design. Moreover, Ecoshape foundation[2] specified that business case development in support of building with nature projects implies several iterative cycles[3].

[1] www.openness-project.eu
[2] www.ecoshape.org
[3] https://www.ecoshape.org/en/news/business-case-approach-for-building-with-nature/

Science-policy-practice linkages
NBS projects require the application of multidisciplinary approaches in the multiple steps of project development. Achieving linkage between science, policy, and practice is usually a difficult task. Although this kind of linkage can be facilitated through dialogue, the lack of common language hinders cooperation by causing misunderstandings (Fletcher et al., 2015; Prudencio & Null, 2018). Consequently, it is important to use capacity building and plain language, when communicating NBS to experts of other fields or to the society at large. However, it is very important to identify the existing linkages first. The production, operation, management, and use of NBS have complicated interrelations with the surrounding space.

"*One of the more important aspects of NBS would be how to consider them in a circular economy and in urban innovation ecosystems. That is, not to simply prioritise among them but to see them in the light of integrated urban development*" (quote from respondents to a ThinkNature survey; results reported in Bernardi et al., 2019).

As the system, where an NBS is planned and implemented, is always very complex, scientific research is often needed to explore, unfold, and evaluate the main items and leverages between the items. Finding important leverages within the system can lead to targeting selected parts of the system via the implied power relations. For instance, a municipal planning strategy can target specific ecosystem services, economic incentives can be created to support investment in specific kinds of NBS, and coercive regulation can deny the use of harmful materials. Therefore, mapping systems, where NBS are allocated, is fundamental for:

- helping urban planners and decision makers identify possible strategic pathways, actions, and NBS interventions;
- overcoming "silos", finding synergies among diverse actors, and suggesting co-financing derived from different sectors;
- revealing knowledge gaps and research needs that exist in the system around NBS; and
- recognising (powerful) stakeholders and entry points for involving local society.

Figure 4.2 gives an example of how the benefits can be portrayed in relation to input, waste, and emissions. It also portrays, how the society can control the system and the economic balance by regulation. However, this figure only depicts one example of many possible ways to map a system; alternatively, the focus could be on mapping how to realise a specific goal (e.g. supporting indigenous declining species with NBS). Focusing on the specific components of this mapping, resource consumption is inevitable when building NBS and unwanted side effects (ecosystem disservices) may arise during delivery stage (Schaubroeck, 2018; von Döhren & Haase, 2015; see also Chapter 3). These need to be compared to the wanted benefits from NBS. Moreover, analysis of the natural resources, land and energy consumption, as well as waste production and emissions to the environment will reveal critical points during the lifespan of an NBS. Identification of critical points will enable optimisation of NBS towards resource efficiency and limited environmental impact. Regulation can effectively affect the choice of products available for NBS and prevent, for instance, the use of invasive species or materials with a high ecological footprint. Coercive regulation is obviously an effective tool, if there are authorities controlling its implementation (see Chapter 7). Finally, in the ThinkNature survey, policy and market drivers and barriers were frequently identified (Bernardi et al., 2019). Therefore, a more detailed identification of these items shown in Figure 4.2 is likely useful (see also Chapters 6 and 7).

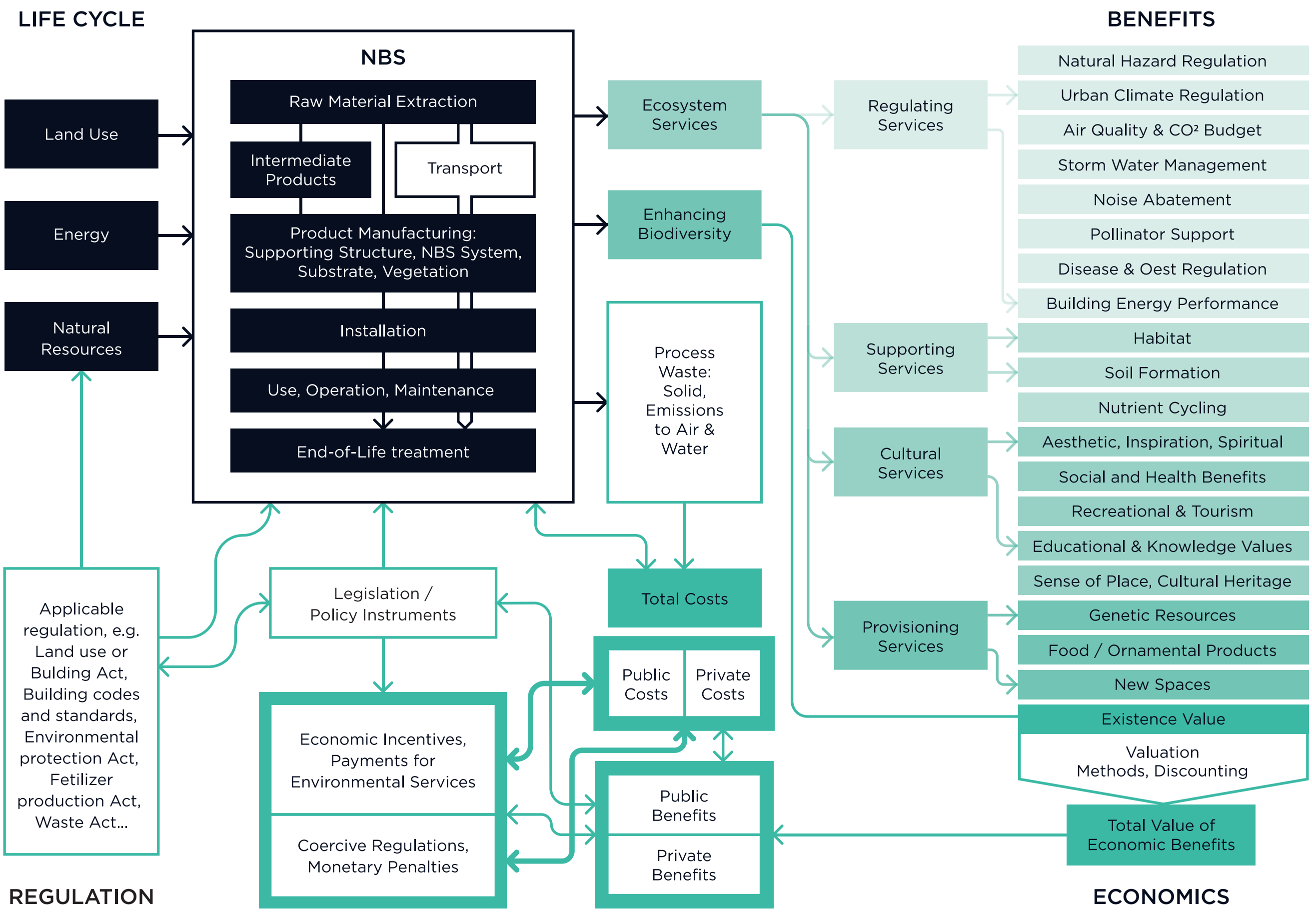


Figure 4.2. An example of a systemic approach regarding NBS depicting the utilities and environmental impacts (Nurmi et al., 2012)

Barriers and drivers

Knowledge gaps and technical barriers (Table 4.2) impede the practice and upscaling of NBS. In general, the knowledge gaps can be classified in terms of:

- Designing, implementing, and maintaining NBS
- Quantifying (including economic valuation) the benefits and co-benefits of ecosystem services provided by NBS
- Monitoring and assessing the effectiveness of NBS

Currently there is both a lack of deep understanding among key actors, and a deficiency of skills that would otherwise enable the selection and the effective implementation of the most appropriate NBS. This weakness results mainly from the lack of appropriate training of planners, developers, and construction professionals. Inadequate technical knowledge regarding the designing and implementation of NBS at the institutional level has been identified as the major obstacle for effective implementation (Naumann et al., 2011). The multifunctionality of NBS, apart from offering multiple benefits, can also present a challenge, especially for those with insufficient skills and experience. In many cases, important actors who could otherwise contribute to overcoming technological barriers are left out from the decision-making process, as an in-depth stakeholder mapping and outreach is absent.

Both decision makers and practitioners often lack the know-how to successfully address possible trade-offs making optimal use of the available technical solutions. On the other hand, technically feasible solutions that are appropriate for addressing multiple challenges are limited and underdeveloped.
In many cases, the lack of ready to use technologies and ready to apply scientific results and concepts makes the adoption of NBS even more challenging. Especially when it comes to novel NBS (e.g. artificial ecosystems, building integrated vegetation), there is a lack of sufficient guidance and technical support in terms of instructions for implementation and maintenance.
As a result, designers may encounter difficulties in implementing NBS as opposed to traditional solutions with which they are more familiar from a technical point of view and also with respect to legal requirements.

There is also a misunderstanding concerning the cost of the techniques for NBS (including maintenance), as this is often mistakenly perceived to be higher than grey solutions. Of course, the fact that NBS are not mainstream, results in a lack of ready and easy to install technical products. This can lead to increased costs for small-scale NBS projects. Expensive technology can be a barrier that stands at the cross-section of the technical and market spheres.

It is important to identify ways that NBS planning is eimbedded in government structures to support co-generation of knowledge for sustainable implementation of NBS at the local level (Table 4.3). The creation of a technical solution may not always have the necessary support in terms of policies, or a new NBS may need change of regulation to become legally feasible (e.g. NBS based on recycled materials). Another example of the interplay of policies is that of spatial policies with technical: planning does not always acknowledges the physical space that is needed for NBS (e.g. for wetlands, rain gardens, and urban farming).

However, even a technically feasible solution is not really well established until it reaches the end-user's consciousness. This makes the technical development hit a knowledge barrier. Albert et al. (2019) emphasised the importance of societal relevance assessments of NBS by quantifying the co-benefits and costs using multimetric indicators. In such cases, the spread of a technical innovation also becomes a social matter, e.g. process- or tradition-based, as a given new technology must fit in the daily culture and routines of the end-users.

Table 4.2. Summary of technical barriers and knowledge gaps

TECHNICAL BARRIERS	KNOWLEDGE GAPS
· Technically feasible solutions appropriate for addressing multiple challenges are limited and underdeveloped · Lack of sufficient guidance-protocols and technical support in terms of instructions for implementation and maintenance · Materials used for NBS are not always environmentally friendly · Lack of ready to use and easy to install technical products · Expensive technology stands at the cross-section of the technical and market spheres · Restrictions of the monitoring methodologies to link NBS impacts across spatial scales (micro to regional) · Poor availability of consistent datasets to evaluate NBS impacts · Accuracy and quality of the monitoring approaches · Quantification of the impacts of heat and drought on NBS and their capacity to continue to provide services	· Lack of deep understanding among multidisciplinary key actors · Lack of appropriate training of planners, developers, and construction professionals · Lack of interdisciplinary skilled personnel · Absent in-depth stakeholder mapping and outreach · Absence of a widely established holistic framework for the assessment of NBS impacts · Absolute lack of data on real maintenance costs · Lack of evidence regarding the quantitative benefits of NBS · Lack of knowledge regarding the impacts of NBS on health and wellbeing · Insufficient or in most cases absent follow-up monitoring of implemented NBS impeding the evaluation of NBS effectiveness · Uncertainty about temporal evolution and long-term effects of NBS · Interdisciplinary methods and research designs to monitor synergies and trade-offs within and across challenges

Rizvi et al. (2015) highlighted the need to develop conclusive evidence to support the effectiveness of Ecosystem Based Approaches to combat climate change impacts. The insufficient, or in most cases absent, follow-up monitoring of implemented NBS impedes the evaluation of their effectiveness and, as such, deprives decision makers and practitioners from valuable conclusions concerning the cost-benefit analysis, the performance, and longevity of NBS. This knowledge gap is greatly due to the absence of a widely established holistic framework for the assessment of NBS impacts across a range of climate resilience challenges and at different geographic scales.

Commonly accepted and evaluated monitoring methodologies that fulfil the basic requirements (see Chapter 4.3) are not yet established. Research and practice of NBS impact assessment is still in its infancy, therefore, there are many knowledge gaps and priorities to be identified for future actions. The issue of monitoring the different scales of NBS impacts in both spatial and temporal dimensions is an important direction for future research.

In many cases, the measurement of impacts may not be reasonable or even feasible at a large scale (e.g. city or regional) because the change caused by a single NBS implementation is too small. For example, the environmental impact of a single green area on city air quality is minor since the amount of pollutants captured by vegetation is only important at the micro-scale (street level). The same holds for water quality, the urban heat island effect, and the carbon storage capacity, as the impacts of spatially limited individual NBS projects (or actions) may be very small. However, one should measure the aggregated effect of all NBS implementations to have a measurable effect in the city scale. This can be accomplished by adopting a common monitoring strategy and the close collaboration among the different NBS projects at the regional scale.

Moreover, most available monitoring technologies and methodologies focus on specific spatial scales and there are major identified limitations to bridge the monitoring results across different observation scales. Another limitation is the absence of methods for translating regional level climate information to the local level. Existing methods of NBS assessment often do not consider individual and community capacity to adapt to climate change.

There is scarce information in the current literature regarding the time for individual NBS actions to become fully effective. Three broad categories can be identified according to (Raymond et al., 2017a; 2017b): short (within 5 years), medium (5-10 years), and long term (over 10 years). The temporal evolution of the NBS impacts can be estimated according to different modelling scenarios, however, there is a great range of uncertainty connected to the behaviour of NBS in complex systems (e.g. urban areas), while climate change remains an unpredictable factor.

Most available research knowledge has focused on the environmental impacts of NBS, while little research and practice has assessed the potential for co-benefits, synergies, and trade-offs across elements of the socio-cultural and socio-economic systems. Further attention and focus must be given on appropriate interdisciplinary techniques to address these gaps. The issue of scale is once again recognised as a major knowledge gap driving the interactions between different contexts. NBS impacts need to be considered within a wider context of climate, social, demographic, and economic trends and patterns. Interdisciplinary, mixed-method research designs can balance the need for qualitative and quantitative assessment of NBS impacts.

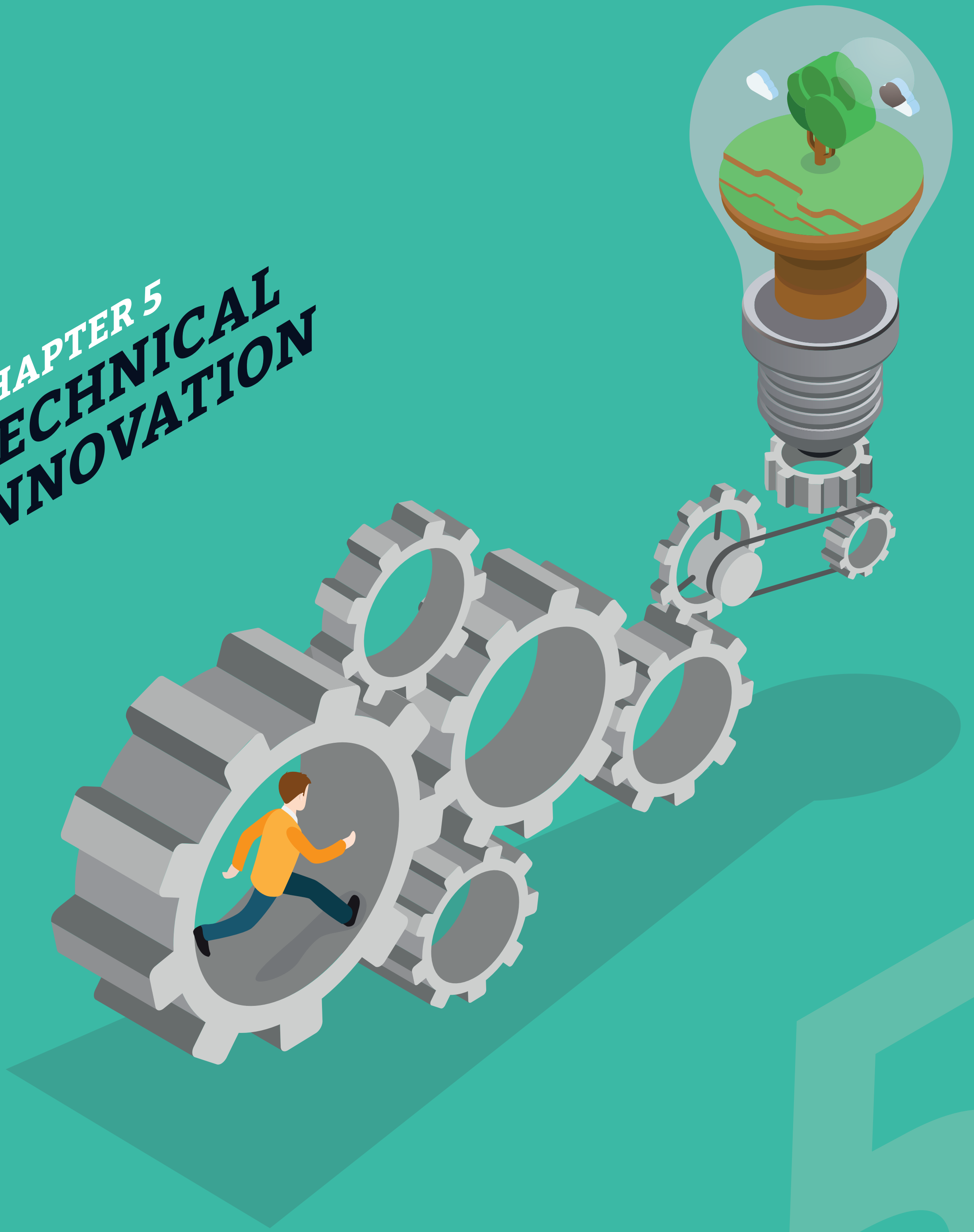
The restricted replicability and harmonisation between monitoring methodologies and datasets is often a major barrier that hinders the comparability between NBS case studies. Research studies on NBS impact assessment include in many cases measurements that are difficult, expensive, or need highly specialised equipment and personnel to undertake. Such data are often scarce and cannot be replicated across case studies. The poor availability of consistent data needed to monitor various aspect of NBS impacts is an important barrier for the development of a common evaluation framework. The use of models is a very widely used strategy for assessing potential impacts based on parameters measured in other contexts. However, the modelling approaches or their application can vary significantly between different cases and among different expertise areas. Even though, for some critical NBS impact parameters, there are numerous methodologies or approaches in the literature, the harmonisation between them in a common framework is still not accomplished for NBS impact evaluation. Moreover, the methodologies and datasets used in the literature to model NBS impacts in many cases need further investigation regarding their consistency, quality, and accuracy.

Table 4.3. Summary of technical drivers and examples of possible actions at various levels.

DRIVERS / ACTIONS	LOCAL	NATIONAL	EU	GLOBAL
Practical/ scientific knowledge and expertise for NBS	**Municipalities** to allocate personnel with expertise and knowledge; **Engage NGOs** as knowledge producers.	Develop Curricula in education at various levels; Train practitioners and ensure quality assurance of NBS projects; Define specific key performance indicators; Recognise knowledge gaps for research and development (R&D) of companies.	Allocate resources for producing knowledge for the recognised knowledge gaps of the performance of various NBS; **Provide easily accessible technical knowledge** for professional communities in their key databases with their own professional language.	Knowledge databases, best practices, cases to be developed and maintained; Companies participate actively in forums, exhibitions, and competitions for the implementation of NBS.
Knowledge and technical support for the maintenance of NBS.	Following the instructions and standards developed in National level.	Provide information and instructions.	Support the development of standards and performance assessment.	Spread knowledge of devices supporting maintenance in a sustainable way.
Development of knowledge/ solutions	Involve experts of various fields to upscale experiences: create guidelines based on the experiences.	Establish working groups under suitable national umbrella organisations.	Organise expert panels around technical challenges with future-oriented approach (e.g. Delphi).	
Demonstration project	Broad stakeholder mapping to involve relevant actors.	Cities, public sector as an innovator, clear and successful demonstrations.	Continuity of EC R&D Programmes financing Innovation actions in the NBS domain (demonstration projects).	
Facilities for piloting/ innovating projects	Experts in the municipal organisation facilitate projects developing new NBS technologies for local solutions.	Instructions for financing organisations.	Resources for long-term follow-up in Horizon 2020 and Horizon Europe projects; Pool of EU cities willing to implement pilots on NbS projects.	ICLEI, UN Habitat, the World Bank and other advocacy organisations to recognise NBS as crucial.
Cost effectiveness of NBS techniques (including maintenance)	Cost effective technologies through digital technologies.		Support the implementation of digital technologies.	

CHAPTER 5

TECHNICAL INNOVATION



5

5 TECHNICAL INNOVATION

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Technical innovation in NBS is progressing rapidly and during the last decade diversified solutions have been developed. As introduced and carefully detailed in Chapter 2, NBS can be classified into three different types according to the degree of intervention/level and type of engineering in the different applied solutions. Innovation is present in all three categories, with technical innovation being more relevant in type 3. Innovation in management and governance prevail in types 1 and 2 of NBS (Annex 1). NBS in the urban context mostly concerns the design and management of new ecosystems or small-scale smart engineering solutions. NBS outside the urban areas focus mainly on agroecosystems, protected areas or parks, green corridors, river basins, and coastal zones. River basins face risks due to excessive precipitation and prolonged periods of drought. Coastal zones, on the other hand, are threatened by climate change, the effects of which are: increased energy of the seas due to higher temperatures, more severe storms and resulting harsh waves, sea level rise. In most cases, nature-based management and adaptation strategies based on the natural processes help towards adaption to climate change, restoration of the natural processes, strengthening of resilience, and reduction of flood risks. A comprehensive list of NBS that are currently implemented in the urban context has been included in Chapter 2 (Annex 1). This chapter will briefly focus on some of those.

Targeting the wide acceptance and implementation of NBS over grey solutions, it is urgent to showcase the effectiveness of NBS in numbers. Once the NBS has been implemented, the evolution and functioning needs to be monitored (Chapter 4). This requires the selection and design of robust monitoring methodologies of high scientific quality and accuracy that are capable of quantifying the multi-scale NBS impacts. Such methodologies are needed for the establishment and the wide acceptance of a holistic framework for the assessment of NBS impacts across a range of societal challenges and at different geographic scales. NBS monitoring methodologies are expected to advance significantly in the near future, stemming from new technological, research, and innovation advancements. Europe's capacity for developing technologies and coherent databases that would foster innovation and operationalisation is foreseen to grow, leading to increased potential towards NBS monitoring and evaluation. New innovative technologies are emerging and give enormous possibilities in the field of NBS monitoring and evaluation. Some examples of the current trends that would aid the establishment of a common NBS impact evaluation framework are given below (section 5.3).

5.1. NBS practices in urban areas

Figure 5.1. "Green roof initiative" in Basel (https://oppla.eu/casestudy/18381)

Extensive green roofs

Green roofs (Figure 5.1) are one of the most interesting solutions for compact and dense urban areas where there is a lack of green spaces. They are a type of green and blue space adaptation solution to climate change, bringing multifunctional benefits. Green roofs, when implemented widely in densely built-up areas (usually as part of supported initiatives), can reduce storm water runoff by 17-20%, enhance biodiversity, mitigate the urban heat island effect, and lower indoor temperatures as much as 5oC. Extensive green roofs, as opposed to intensive green roofs, require minimum irrigation and have lower construction and maintenance costs. They are also less likely to cause damage to buildings, as long as an appropriate growth system is implemented.

Green covering shelters

Technically, this NBS is similar to an extensive green roof, but it can only be installed in small or big coverage infrastructures, such as bus shelters or existing covering shelters (Figure 5.2). It can be placed in dense city centres and can contribute to the reduction of the heat island effect. It needs minimum maintenance and contributes to balancing the relative humidity. It contributes to decreasing the negative impact of heat waves and improves well-being providing physical coverage for sun and rain. Further experimentation of these kinds of small-scale NBS is particularly encouraged, as a single failure in terms of lack of growth will not be costly, while there is a high opportunity for learning from piloting different technical solutions.

Figure 5.2. Green shelter, property and sourced from URBAN GreenUp project, funded by H2020 program. (https://www.urbangreenup.eu/solutionsnn/green-covering-shelters.kl)

To be effective and sustainable, all types of innovative and high-quality performance NBS should include the following principles, whenever possible:

1) use recycled materials;

2) use renewable energy and target energy savings;

3) minimise irrigation or re-used water;

4) avoid plastics, leca, mineral wool, and other materials with potential heavy environmental footprint;

5) target simple systems;

6) do not use invasive species - favour local native ones;

7) use local materials, e.g. on-site soil and seed bank;

8) combine NBS with solar panels;

9) make sure irrigation is available at installation;

10) install fire breaks where needed;

11) install safety railings and fall prevention device for installation and maintenance.

Figure 5.3. Public school green roof garden in New York City (https://www.flickr.com/photos/inhabitat/8090009142/in/photostream/)

Coupling green roof and urban farming

Coupling green roof and urban farming can provide multiple benefits to the environment and the community. This pioneering solution aims to transform the relationship people have with their food. Several examples exist across the world, with New York[1] (Figure 5.3), Berlin (Wunder, 2013) and Hong Kong[2] being the frontrunners in this sense. In terms of construction details, several examples exist, based on the type of building, the climatic area of the city and, of course, the desired type of fruit and vegetables. Drainage and irrigation can be automated making use of collected and stored rainwater. A closed water system is usually needed to avoid contamination of surface waters with nutrients. Moreover, high quality and organic seedlings, soil and sustainable gardening are demanded.

Figure 5.4. Herb garden in Southmead Hospital, United Kingdom (https://oppla.eu/casestudy/19175)

Therapeutic gardens

Increased attention is now being paid to the use of NBS to improve people's health and wellbeing. In this sense, the implementation of therapeutic gardens, which started several years ago in hospitals (Figure 5.4) and similar structures, is now spreading wider into parks, gardens, social centres, and local associations. These gardens normally have different sensorial areas with very different types of plant species that stimulate the senses of people passing by.

Vertical mobile gardens

Similar to the concept of green facades and vertical gardens, vertical mobile gardens (Figure 5.5) can be really useful in dense urban neighbourhoods

[1] https://www.brooklyngrangefarm.com/
[2] https://www.rooftoprepublic.com/

Figure 5.5. Vertical mobile garden, property and sourced from URBAN GreenUp project, funded by H2020 program (https://www.urbangreenup.eu/solutionsnn/green-covering-shelters.kl)

Figure 5.6. CityTree in Copenhagen, (©InvestEU). (https://greencitysolutions.de/en/)

and city centres. Modular planting systems containing a growing medium of natural peat bock are available in the market (Margolis & Robinson, 2007). The panels are mounted on a stainless-steel aluminium frame anchored into an adequate structure, creating a living cladding. Water can be supplied to the plants through a drip irrigation system. The anticipated maintenance for such systems is low, however the initial cost is rather high.

The flexibility and adaptability of mobile gardens makes them easy to install in several different places (home, office, shops, and streets), while green facades could sometimes be harder to implement due to construction restrictions and building design. Vertical and mobile gardens can be used to shield buildings and windows from heat, noise, rain, sunlight, and UV radiation and can contribute to the natural conditioning of buildings and outer spaces. Mobile gardens can also be moved from one place to another optimising different seasonal conditions and light exposures. In terms of material used, vertical mobile gardens can be made from recycled or reclaimed materials (recycled lattices, re-used wood), making this NBS a perfect example of a nature-based and circular solution.

CityTree (Figure 5.6) developed by Green City Solutions is an innovative mobile installation which removes air pollutants through a combination of mosses and controllable ventilation technology. Integrated sensors measure the local air quality, soil humidity, temperature, and water quality. The installation is autonomous and requires minimum maintenance. Solar panels provide electricity and rainwater is collected and then used for irrigation.

Figure 5.7. A Green wall for a kindergarten in Yerevan (https://oppla.eu/casestudy/18930)

Green barriers

In certain cases, such as in neighbourhoods close to transport infrastructures, air pollutants and noise from vehicles impact the ambient environment. One easily implemented NBS that requires limited care, is green barriers (Figure 5.7) formed by creeper plant species on simple bearing structures. Such green barriers prevent the penetration of pollutants from vehicular emissions and enable the reduction of traffic noise by up to 15dB with a low cost and reasonable maintenance requirements. Another more technically advanced alternative consists of Green Noise Barriers (Figure 5.8) which are implemented using innovative substrates with specific plants, mounted on specially designed structures. Such green barriers are designed to allow passage of wind, thus reducing wind loading. The evidence of the effectiveness and cost/benefit for implementation of such solutions varies mostly depending on local climate and building standards. Pilot projects that report the technical performance of vertical greening are still in high demand (Raji et al., 2015).

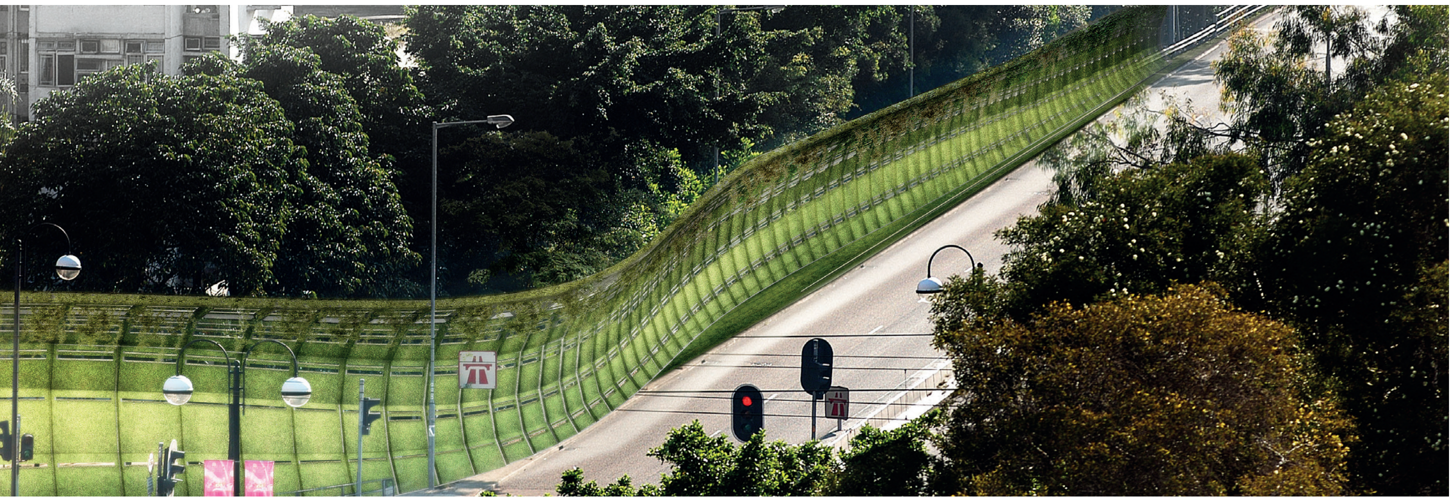

Figure 5.8. Green noise barrier, (©ESKYIU). (http://eskyiu.com/linear-landscapes/)

Figure 5.9. Adaptation Support Tool (https://www.deltares.nl/en/software/adaptation-support-tool-ast/)

Urban planning tools
Urban planning strategies are slowly starting to incorporate Ecosystem Services and NBS principles in their priorities. An interesting case is that of the city of Genk, aiming to redevelop the natural and heritage capitals of the city itself. Genk's multi-annual strategic plan for 2014-2019 is a response to the closure of the biggest industry of the area and includes as a main objective the exploitation of natural and human capital for sustainable value creation[3]. This process can be boosted with of innovative tools such as the PPGIS (Public Participation Geographic Information System) (Brown & Raymond, 2014). In this sense, the Adaptation Support Tool[4] (Figure 5.9) was developed by DELTARES, a Dutch research Centre, visualising possible benefits of NBS.

Various tools that can assess the impacts of NBS on urban metabolism and offer a decision support system linking the bio-physical processes in urban environment with socio-economic parameters, have also been developed by BRIDGE FP7 project[5].

To better understand the provided services of green areas and NBS, it is crucial to account the available public green spaces, their functions, their accessibility and their value. Data on land use are therefore necessary for cities and rural areas as they enable better understanding of the classification, the proportion, and the value of the land. In this sense the CORINE Land Cover data[6] and the Urban Atlas[7], provided by Copernicus Programme, strongly support cities that do not have their own databases of land use. Also, useful

[3] https://platform.think-nature.eu/nbs-case-study/19455
[4] https://www.deltares.nl/en/software/adaptation-support-tool-ast/
[5] http://www.bridge-fp7.eu
[6] https://land.copernicus.eu/pan-european/corine-land-cover
[7] https://land.copernicus.eu/local/urban-atlas

insights have been provided by the Urban MAES pilot[8], that provides indicators, tools, maps, and innovative methodologies for evaluating the distribution and the value of ecosystem services in European cities.

Figure 5.10. Adaptation of Bratislava city to Climate Change (https://oppla.eu/casestudy/19033)

Integrated water management strategies
Integrated water management is one of the main challenges faced throughout Europe. Most climate-change related effects, such as floods, droughts, and extreme weather events increasingly affect our cities. Therefore, more efficient water storage, treatment, use, and management are needed that would also reduce the impact of natural disasters (UN-Water, 2018). Within the overall strategy of circular economy, the EU commission is also boosting the concept of water reuse (EC, 2016). In this sense, it is increasingly common to develop closed biosystems (i.e. lake, landscape elements in the street) that use plants to purify wastewater before reintroducing it into the system or using it for other purposes (mostly irrigation). Water management strategies and action plans in relation with other relevant urban policies can be most effective. A good example of this approach is found in Bratislava, Slovakia (Figure 5.10), where the pilot application of adaptation measures has taken place[9]. The integrated strategy has been complemented by communication activities with institutions, NGO, and public. Following repeated heat waves, droughts, fluvial and pluvial flooding, and other extreme weather events, and in order to protect citizens and to minimise the carbon footprint of the city of Bratislava, an action plan was developed for climate

[8] https://biodiversity.europa.eu/maes

[9] https://platform.think-nature.eu/nbs-case-study/19033

adaptation. In this context, green and soft adaptation measures that maximise the use of rainwater and green infrastructure were implemented. Green areas were created, a water management scheme as well as Vulnerability Analysis and Planning Tools were put in practice, with the majority of the implemented interventions representing different forms of SUDS, green roofs, or rain gardens. The action plan, which can be widely replicated, was integrated into the core strategic document of the city and the commitment was declared at an international level through Covenant of Mayors and Mayors Adapt during the last years.

Figure 5.11. Nature-Based Storm Water Management in East London (https://oppla.eu/casestudy/17562)

Sustainable urban drainage systems (SUDS)
To improve surface permeability and the drainage systems of dense urban areas, SUDS have been demonstrated to be an efficient and cost-effective solution. Several kinds of SUDS can be implemented in cities depending on the area and the main functions they should provide: permeable pavements, filtering trenches, retention basins, filtering strips, filtering canals, tree boxes filters, vegetated canals, planted retention areas, ponds, rain gardens. Examples of innovative solutions can be found in several SME and large industries around Europe, with SUDS being among the most integrated NBS into the market. For instance, Hydro International, in the United Kingdom, has developed several innovative SUDS, such as the Hydro Biofilter™, a high-amenity biofiltration system that uses soil and filter media to treat an assortment of course, fine, and dissolved storm water pollutants[10].

In East London, addressing the challenge of storm water management, a multifunctional SUDS planning guidance with a focus on biodiversity-friendly solutions, suitable for high-density urban areas, was developed[11] (Figure 5.11). This was showcased in a multifunctional pocket park. Urban biodiversity knowledge, SUDS design understanding, and silo busting among the different departments of the Local Authority, were paramount for the success of this project.

[10] https://www.hydro-int.com/en/products/hydro-biofilter
[11] https://platform.think-nature.eu/nbs-case-study/17562

Blue-Green Approach
The **Blue-Green Approach** develops a synergistic relationship between conventional infrastructure and Blue-Green solutions, integrating climate adaptation solutions within the limited confines of urban space, encouraging a solution utilising the best of both techniques.

The **Copenhagen Cloudburst Management Plan**, developed after an extreme 1000-year storm event in July 2011, is a very good example of a Blue-Green Approach (Figure 5.12). Integrated, multi-disciplinary plans bridge the gap between planning and site-specific solutions through the application of a typology-based **Cloudburst toolbox**.

Cloudburst toolbox: eight Urban Intervention Tools were developed to mitigate common urban typologies streets, parks, and plazas. The Cloudburst toolbox combines hydraulic engineering (the "Grey") with urban ecological engineering (the "Blue-Green"), for establishing a model for universally applicable flood mitigation strategies.

Transferability: Blue-Green infrastructure is the future for establishing urban ecological waterscapes while balancing sound investment and economic opportunities with social benefit improvements. It represents the next generation of water infrastructure considerations where nature, city and recreational space are rolled into a holistic package. Cities around the world can look to the Copenhagen Cloudburst Formula as a model for implementing innovative, pragmatic, feasible measures within existing urban fabric.

Figure 5.12. 6 step procedure for the integration of the Blue-Green Approach in Copenhagen Cloudburst Formula (https://oppla.eu/casestudy/18017)

5.2. Rebuilding nature in the landscape

Peri-urban parks
Natural parks near urban population centres are precious assets that support human well-being. They function as carbon sinks while preserving and enhancing the diversity of local biotopes. Innovative governance and administration models are vital in peri-urban landscapes (Figure 5.13). Brownfields should be prioritised and revitalised to become valuable public spaces. For better connectivity between city and park grounds, transport infrastructure should include bike lanes.

Figure 5.13. Peri-urban park in Prague (https://oppla.eu/casestudy/18911)

Green corridors
The natural landscape in Europe is being fragmented as population pressure increases. Natural zones, whether or not protected under the Habitat directive, are disconnected from each other with negative impacts for wildlife and biodiversity. Applied nature-based strategies reverse this trend. Isolated natural reserves can be reconnected via green corridors forming networks that allow populations of wildlife to move between natural zones. The City of Lisbon has taken a series of measures towards connecting green spaces by creating green corridors (Figure 5.14), in the context of a Master Development Plan. A municipal protected forest in the outskirts of Lisbon is connected to a public city park in the centre of Lisbon, through the creation of a “green corridor” that includes street trees, new green areas, bike lanes and pedestrian streets. Such green corridors can also be coupled by eco-ducts; a form of infrastructure spanning above motorways in order to link between two natural zones.

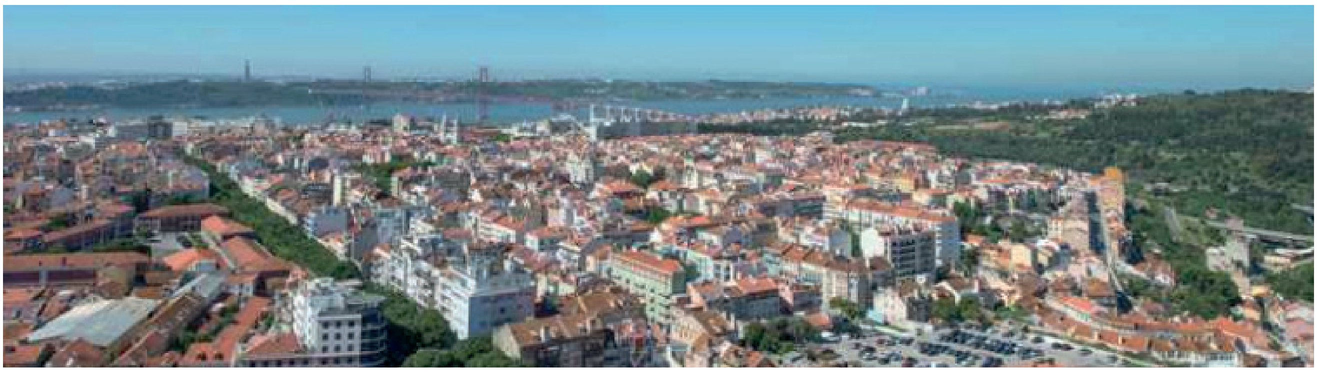

Figure 5.14. Lisbon Green Corridor (https://oppla.eu/casestudy/17624)

Rural land management: Agroforestry
Rural land, be it agricultural or otherwise, was traditionally smaller scale with a very diverse flora and fauna. Population pressures and modern agricultural practices have changed the appearance of many landscapes and introduced large scale monocultures. The result is a severe loss of biodiversity, including a severe loss of pollinators, and a landscape that is less attractive.

A successful example of NBS for sustainability and multifunctionality of managed ecosystems is the innovative agroforestry scheme adopted in Montpellier, France (Figure 5.15). This scheme consists of a combination of trees and crops cultivation. The implemented solution allows for the diversification of the farm activity making use of the complementarity between trees and crops so that the available resources can be more effectively exploited. It is a practice that respects the environment with an obvious landscape benefit. Agroforestry leads to a 40% increase in productivity, while being less vulnerable to climate change and its related risks. Trees provide shelter to crops and control damages due to high temperatures. Biodiversity is increased, wind erosion is reduced, and flooding damages are prevented. Soil and water quality are improved, also preventing erosion. However, agroforestry schemes are a long-term investment, as it takes time for trees to mature and provide their functions.

Figure 5.15. Agroforestry in Montpellier (https://oppla.eu/casestudy/18469)

Constructed wetlands
Existing wetlands are valuable biotopes that play an important role in hydrological cycles, they support a rich biodiversity, they are capable of purifying contaminated water while most of them store significant amounts of carbon. Wetlands can also be man-made engineered systems, designed and constructed to utilise the natural functions of wetland vegetation, soils, and their microbial populations to treat contaminants in surface water, groundwater, or waste streams. At the current stage of technology development, three types of wetlands are widespread (Kadlec & Wallace, 2009, Figure 5.16):

- Free water surface (FWS) wetlands with areas of open water. These are similar in appearance to natural marshes.

- Horizontal subsurface flow (HSSF) wetlands, which typically employ a gravel bed planted with wetland vegetation. The water, kept below the surface of the bed, flows horizontally from the inlet to the outlet.

- Vertical flow (VF) wetlands that distribute water across the surface of a sand or gravel bed planted with wetland vegetation. The water is treated as it percolates through the plant root zone. Biosolids dewatering wetlands can be thought of as a type of VF wetland system.

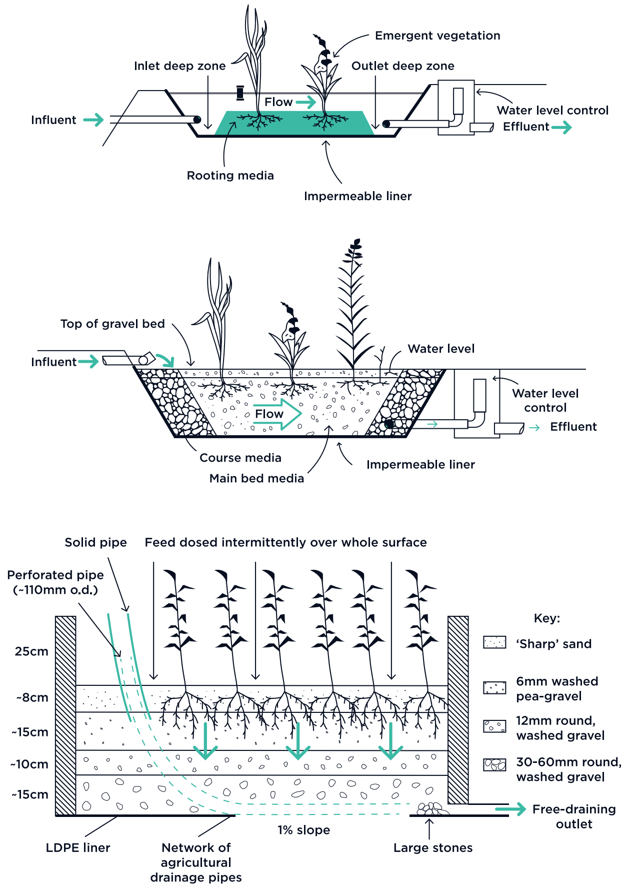

Figure 5.16. Typical arrangement of FWS, HSSF and VF constructed wetland (Cooper et al., 1996; Wallace & Knight, 2006)

Figure 5.17. Constructed wetland in Gorla Maggiore, Italy (https://oppla.eu/casestudy/17252)

Each of these major categories employs variants of the layout, media, plants, and flow patterns. Constructed wetlands, apart from forming an effective, environmentally friendly means of treating waste water, can also provide ecological and even social benefits.
In Gorla Maggiore, Italy (Figure 5.17), constructed wetlands were used instead of a traditional grey infrastructure to treat sewage overflows. It was demonstrated that the multi-purpose green infrastructure (constructed wetlands and park) performed equally to or even better than the grey alternative at the same cost. Wildlife support and recreation were among the additional benefits provided, and were highly valued by the local community
In terms of technical innovation, a very interesting NBS is the 'electric wetland'. It consists of a constructed wetland surface that produces electricity through microbial fuel cell technology[12]. Wastewater treatment efficiency is also improved resulting in lower wetland surface requirements when compared to conventional wetlands. Electro constructed wetlands require low construction/installation and low operational costs and can treat different types of wastewaters (domestic, industrial, etc.) with different pollutants and loads (Narayan et al., 2018).

[12] https://www.urbangreenup.eu/solutions/electro-wetland.kl

An NBS toolbox for river basins

Naturally flowing rivers have defences against excessive high and low water levels. It is typical that flood plains adjacent to river beds accommodate excessive flows. Meandering patterns of rivers result in higher water storage capacity, whereas adjacent wetlands or marshes provide buffer capacity to cope with droughts. However, human pressures have an enormous impact on the natural defences of rivers against high and low water levels. Floodplains are often used to construct houses or industrial facilities, while in order to reduce the risk of flooding, dikes or levees are often constructed. For navigation purposes, excessive meandering is often countered by straightening stretches, while the water level is artificially maintained at a certain depth by constructing dams and locks. The above result from an inability of many river basins to cope adequately with floods or periods of extreme droughts and thus pose major risks, especially to urban zones built on the river banks.

The nature-based answers to these threats are (Figure 5.18):

- Recovering the floodplains where possible (dike relocation)
- Provision of more storage capacity (increasing the volume of the riverbed by deepening, widening, providing overflow levees near the river)
- Increased buffer capacity to delay water flow by restoring some of the meandering that existed previously, by de-poldering and dike displacement, by providing parallel channels to the riverbed and/or by (re-)creating wetlands in the riparian zones

Additionally, vegetation zones in front of dikes (such as a zone of willow trees), can be used to break the force of the incoming waves allowing the reduction of the safe height of the dikes. Riverbank restoration can be coupled with riparian forest restoration, with additional benefits of enhanced water quality and biodiversity.

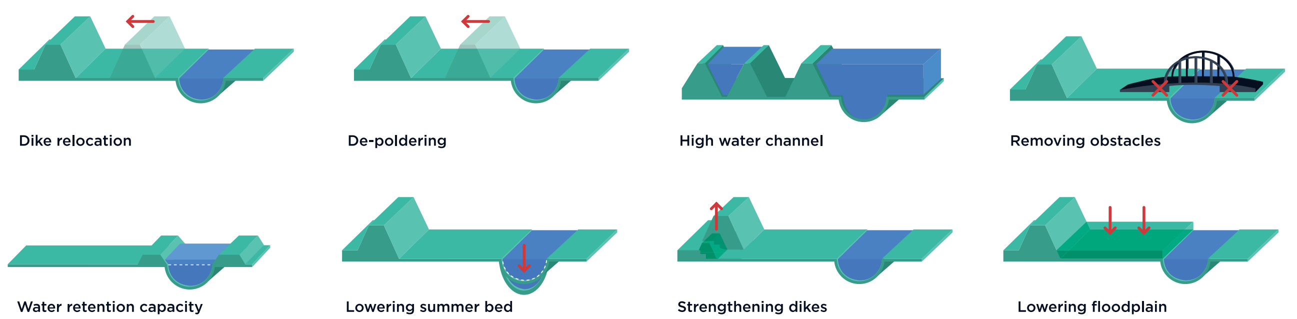

Figure 5.18. River basin management techniques illustrated in sketches (http://www.roomfortheriver.com/)

Coastal protection

The strategies developed to cope with coastal erosion effects are based on retreating, defending the coastline, or even on expanding the coastline (reclaiming land). Nature-based elements introduced to protection strategies enhance the protection function of either natural barriers or support engineered structures, making their functioning more natural. Many combinations are possible. Coastal defence systems can be shaped by man-made structures (seawalls, dikes, breakwaters, groins), by combinations of natural, man-made, or enhanced nature-based features (hybrid systems), or by completely natural elements. Dunes and sandy beaches, mangroves and saltmarsh systems are prime examples of ecosystems that provide a high level of flood protection, while at the same time resisting erosion (Figure 5.19). Under favourable circumstances they can keep track with sea level rise. Some natural elements could be strengthened by the role of ecosystem engineers. ‘Ecosystem engineers’ are those species that can provide services similar to man-made intervention. Hybrid systems either strengthen the natural defence with engineered features (e.g. artificial barrier island in front of mangroves coast), or they add natural elements to an engineered structure (e.g. created wetland in front of seawall). An example of soft engineered protection can be found in Medmerry, in South East England[13]. Coastal systems are often made more resilient by enhancing/ restoring the natural elements, with a widespread practice being the supply of sand to beaches subject to erosion (beach nourishment)[14]. Coastal defences should be approached as tiered systems consisting of several elements interacting dynamically. Restoration of natural coastal biotopes is possible, but demands an in-depth knowledge of the characteristics and vulnerabilities of these biotopes.

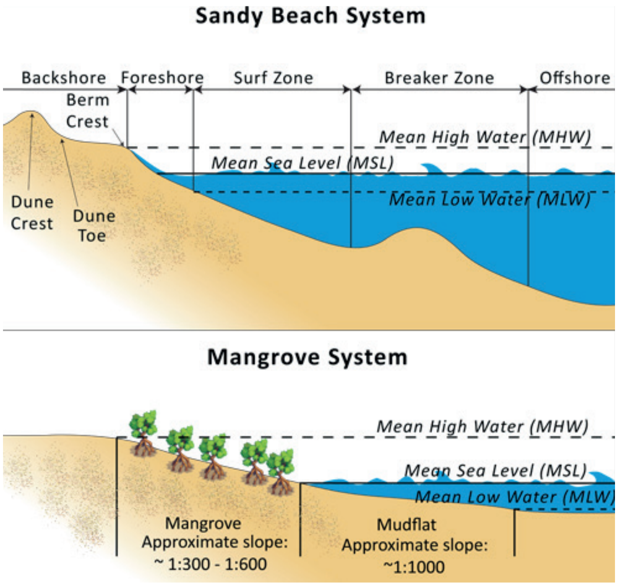

Figure 5.19. Examples of coastal systems (https://coast.noaa.gov/data/digitalcoast/img/tools/invest_3.jpg)

[13] https://platform.think-nature.eu/nbs-case-study/18379
[14] https://platform.think-nature.eu/NBS-case-study/17630

5.3. Monitoring technologies

Earth Observation
In the framework of Copernicus and beyond, Earth Observation (EO) presents tremendous and extremely rapid advancements during the last decades. Satellites provide vast information in both spatial and temporal scales, capturing the state of the environment of a targeted area in the past (baseline) and offering continuous long-term monitoring. EO can deliver affordable, high quality mapping and monitoring of urban and environmental parameters in multiple spatial scales. Latest technological improvements offer higher spatial and temporal resolution along with improved accuracy (Figure 5.20). Current EO trends include low-cost micro-satellites in large constellations and high-altitude pseudo-satellites (HAPS) that provide unprecedented spatial and temporal resolution monitoring. Recent research and innovation actions in the field of EO indicated the potential of new satellite missions to measure urban climate variables such as thermal behaviour and energy exchanges on a local scale (Chrysoulakis et al., 2018)[15], as well as to support nature-based shoreline protection schemes[16]. Overall, the use and availability of EO data in support of NBS monitoring schemes is projected to increase exponentially in the near future, taking advantage of the enormous monitoring capabilities of EO.

Figure 5.20. Copernicus Sentinel-2B satellite image, showing Thailand's most populous city Bangkok, and its 'Green Lung' Bang Kachao (Image credits: ESA, CC BY-SA 3.0 IGO - http://www.esa.int/spaceinimages/Images/2019/03/Bangkok_s_green_lung)

[15] http://urbanfluxes.eu
[16] http://www.fast-space-project.eu/

Figure 5.21. The Sentinel family of satellites designed by the European Space Agency for the operational needs of the Copernicus programme. Each Sentinel mission focuses on a different aspect of Earth observation; atmospheric, oceanic, and land monitoring (Image credits: ESA CC BY-SA 3.0 IGO - http://www.esa.int/spaceinimages/Images/2014/02/The_Sentinel_family)

Copernicus Programme

Copernicus is the European Union's Earth Observation (EO) Programme in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies, and Mercator Océan. Copernicus aims to aid decision making in a world facing increasing environmental and socioeconomic pressures. The programme includes vast amounts of global data from satellites and from ground-based, airborne, and seaborne measurement systems. The space component comprises of ESA's five families of dedicated Sentinels (Figure 5.21) and contributing missions from other space agencies. Copernicus offers solid databases of important in-situ and EO-based measurements, along with modelled parameter estimation, providing a unique potential for data harmonisation and standardisation. The data provided are freely and openly accessible to its users. To facilitate and standardise access to data, the European Commission has funded the deployment of five cloud-based platforms providing centralised access to Copernicus data and information, as well as to processing tools. These platforms are known as the DIAS (Data and Information Access Services). Copernicus datasets are stretching back for years and decades, ensuring the long-term monitoring of changes. There are six thematic streams of Copernicus services: land, marine, atmosphere, emergency management, security, and climate change. Future developments of these core services include more innovative products, cross-cutting applications, increased scientific and operational exploitation, and higher resolution outputs.

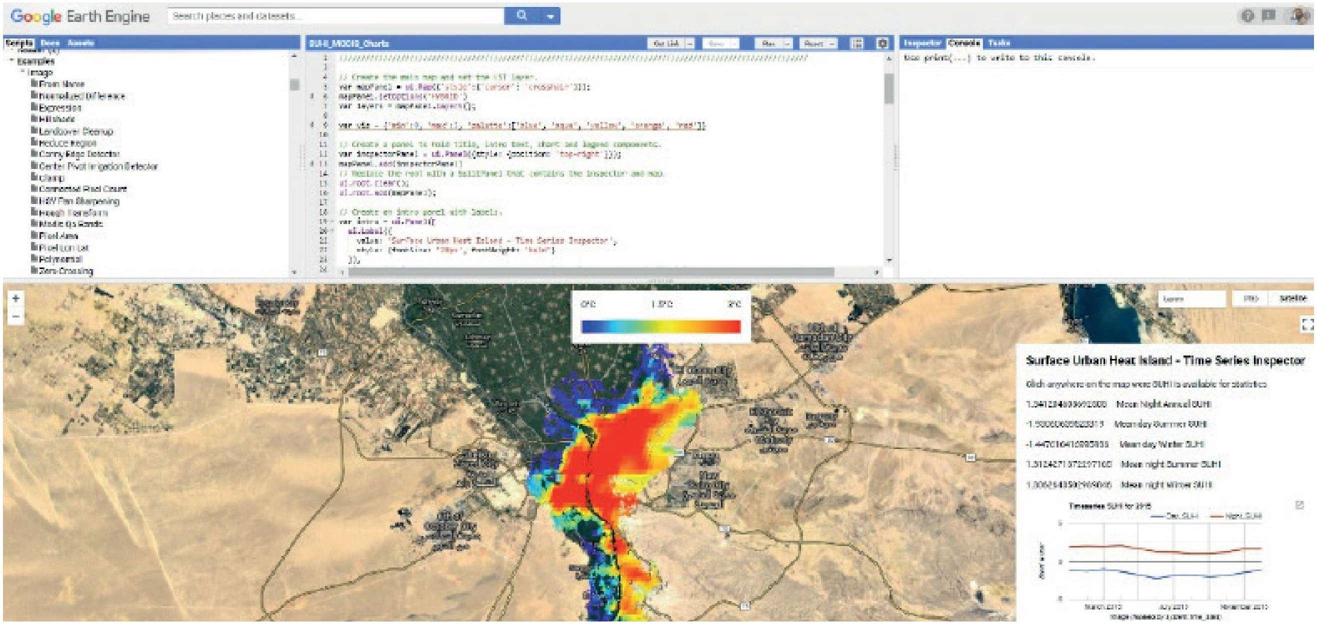

Figure 5.22. Google Earth Engine (GEE) can be used to process massive amount of EO data. The illustration shows a GEE app developed by www.rslab.gr to monitor Urban Heat Island across the whole globe using the complete archive of NASA MODIS observations, (©RSlab).

Big Data

Datasets grow rapidly mainly by the new technologies in communication, networks, media, measurement systems, and storage capacities. This new era in data availability, collection, and analytics gives enormous capabilities for research and investigation in multiple scientific fields. There are even new research fields born due to the challenges and opportunities raised by the new types of data. For social sciences, Big Data today provides extensive potentials for analyses and investigation, when data were scarce for many decades. Big Data provide opportunities for major socio-economic investigations of real-world problems. However, Big Data interferes with great privacy and confidentiality issues that need to be handled accordingly. In Earth sciences there is also a vast amount of data generated every day consisting of Earth Observations and data simulations.

New methods and tools are developed to handle Big Data storage and processing (e.g. Parastatidis et al., 2017). Google has developed Google Earth Engine (Figure 5.22), the EU is developing Copernicus DIAS platform, while U-TEP is an ESA initiative which aims to employ of modern IT services to bridge the gap between EO Big Data and the information needs of environmental science, planning, and policy related to global urbanisation. At the same time, citizen science is advancing and providing encouraging results for new types of analyses and data gathering techniques. There is huge potential for data gathering via citizens' observatories although it requires a strong effort for boosting participation. NBS monitoring methodologies can undoubtedly take advantage of the Big Data opportunities for both environmental and socioeconomic impact assessment.

Modelling Capabilities

Modelling is a fundamental part of the monitoring methodologies. In all aspects of NBS impact assessment, modelling approaches are needed to derive the desired parameters, integrate different input datasets, change observation scale, develop scenarios, and multiple other uses. The transcendent advantage of modelling is the capacity to be transferred, adapted, replicated, and compared across case studies and settings. Technological advances are providing enhanced capabilities for the model complexity, sophistication, and the amount of input data used. Enhanced techniques arise in multiple scientific fields, such as Artificial Intelligence (AI) approaches and modelling techniques, including Machine Learning (ML) algorithms and models (e.g. artificial neural networks, support vector machines, Bayesian networks). Beyond standard fine scale CFD models (i.e. Envi-met[17]) and local scale semi-empirical models (i.e. SUEWS; Sun et al., 2019), enhanced modelling approaches are advancing rapidly in multiple applications and scientific fields, including environmental modelling, Earth Observation, healthcare, finance, and socioeconomics (Figure 5.23). They can serve as powerful tools in co-design and decision making for NBS, as they allow simulation of different alternative solutions, and contemporary demands of climate adaptation and mitigation aspects can be included in the decision-making process. New modelling techniques can be used for assessing the projected impacts of NBS across different challenge scenarios, and across time, or even to predict the status of NBS and their expected impacts in the future.

In-Situ Measurements and Networks

The technology of the in-situ measurements and networks has also advanced in the recent years, updating the observational capacity of multiple processes. The smart and low-cost sensor network

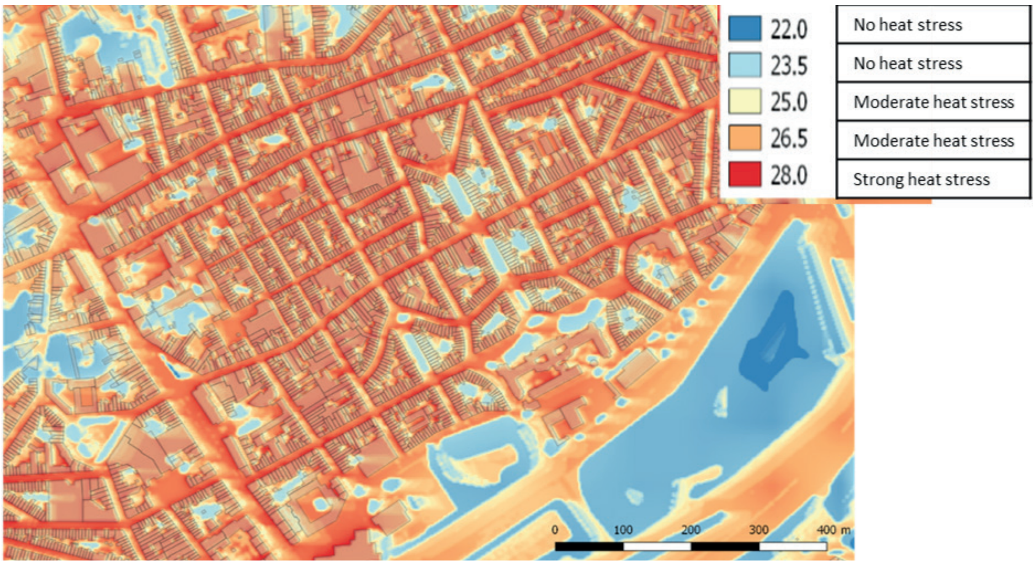

Figure 5.23. Combining urban climate modelling with citizen science to estimate heat stress in cities. Example from Antwerp campaign (2 weeks during summer 2018) (©VITO)

[17] https://www.envi-met.com/

technologies have been developed under mainly the framework of Wireless Sensor Networks (WSN) (Figure 5.24). WSN are today widely applied in monitoring physical or environmental conditions with multiple applications in urban areas (e.g. air pollution, traffic, meteorology, noise), natural environment (e.g. water quality, animal tracking), risk management (e.g. landslides, forest fires, flooding, earthquakes), industry (e.g. waste monitoring, machine conditions) and health (e.g. physical state tracking, health diagnosis). Dense WSN give the potential of low-cost continuous monitoring of several parameters in urban areas and can be used to provide baselines and evaluate NBS environmental impacts. However, the placing of sensors can be challenging in complex environments (e.g. cities) in order to efficiently monitor NBS environmental effects (e.g. temperature reduction) through WSN. Moreover, ground remote sensing (Ghandehari et al., 2018) and drone technology (Stagakis et al., in press) show very rapid evolution during the last decade, offering possibilities for enhanced spatiotemporal monitoring of multiple urban and rural environmental characteristics and processes. Furthermore, new technological and methodological advancements in the scientific area of microclimatology are currently the state-of-the-art for the in-situ monitoring of complex environmental parameters such as CO2 and heat exchanges. Specifically, Eddy Covariance has gained increased attention over the recent years and its application over urban areas to measure the actual CO2 (Stagakis et al., 2019) and heat emissions (Feigenwinter et al., 2018) is a promising approach for the evaluation of actual environmental impact of NBS in the urban setting.

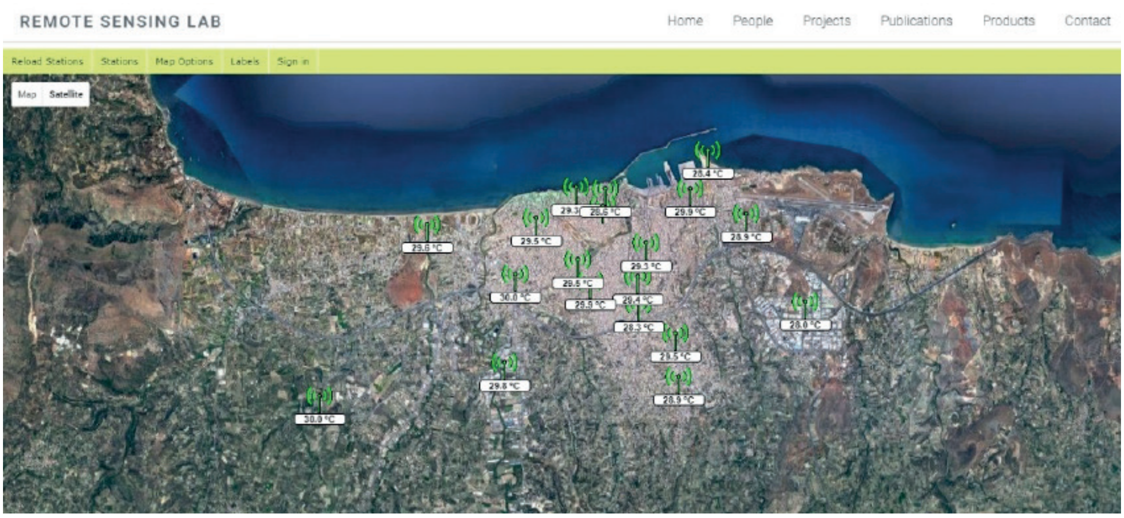

Figure 5.24. Wireless Sensor Network (WSN) of meteorological stations installed and operated by www.rslab.gr across the urban area of Heraklion, Greece. The Heraklion WSN (http://www.rslab.gr/downloads_urbanfluxes.html) was installed to support H2020 URBANFLUXES project, where Heraklion was a case study for monitoring urban heat fluxes using EO and in-situ datasets. It has been operational since 2016 and consists of 17 autonomous meteorological units at various locations and one Eddy Covariance station in the centre of the city, (©RSlab).

CHAPTER 6

FINANCING & BUSINESS

6 FINANCING & BUSINESS

6.1. Economic Opportunities of Nature-Based Solutions

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While nature-based solutions (NBS) are often more cost-effective than traditional grey infrastructure alternatives, the barriers to implementation are more complex and are linked to change management, education, partnership working, and securing investment for an emerging and less understood sector. More information about NBS implementation issues are given in Chapters 3, 4, and 5 of this handbook.

Defining a clear business case and securing financing for NBS is a prerequisite to their success, but key barriers remain for those who wish to implement such schemes. Many struggle to articulate the multiple benefits of NBS in financial terms, often due to limited or restricted data, limited research into quantified benefits, and lack of coordinated knowledge transfer – which in turn can hinder the development of a well-defined business case.

This section explores some of the nuances, opportunities, and tools to help practitioners best make the case for investment in a proposed NBS, which can further unlock new economic opportunities.

To put this in context, the development of a business could follow a series of steps (Figure 6.1).

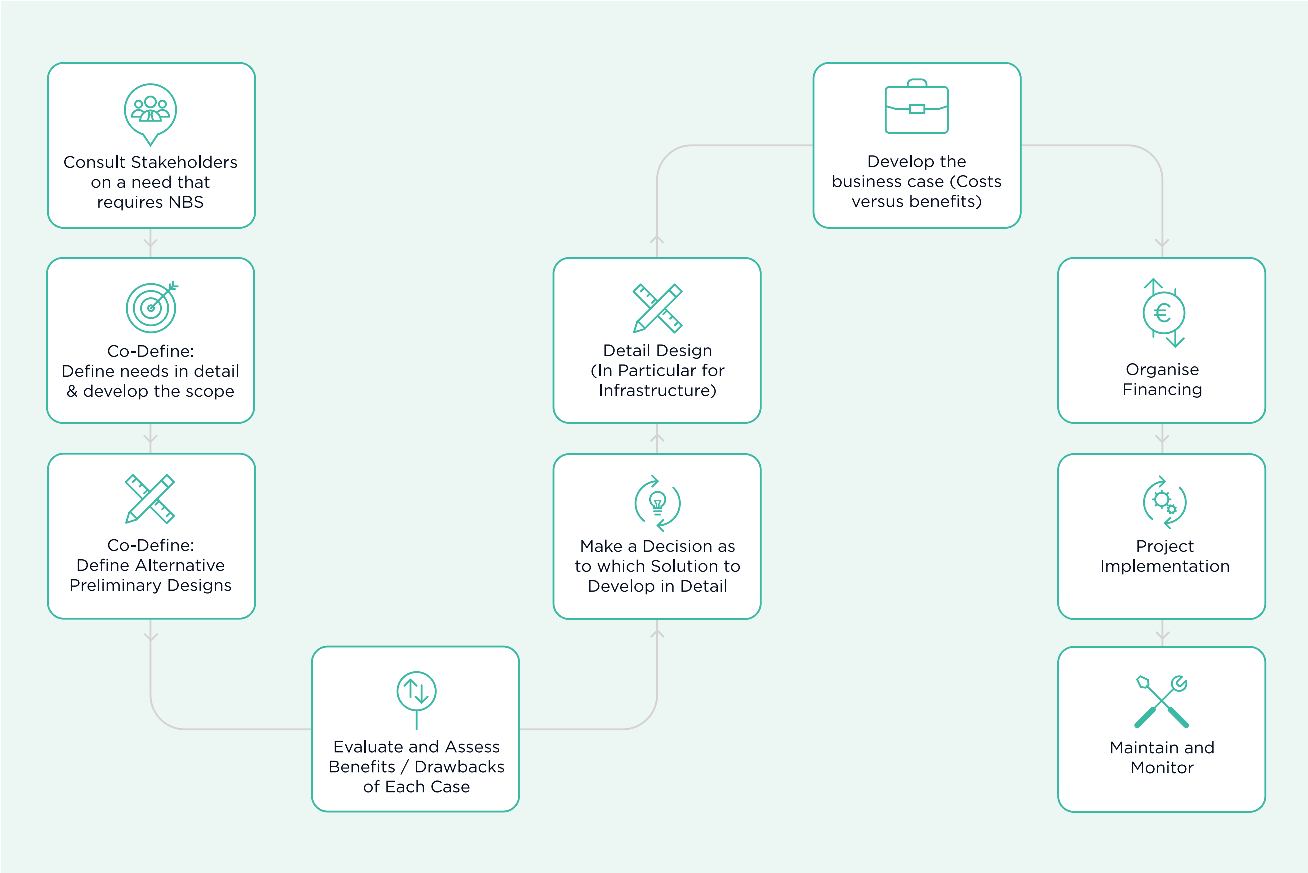


Figure 6.1. Steps in the development of a business case

Identifying the opportunity

The first step in determining the business case for NBS is understanding the need(s) for which a well-designed NBS could deliver a holistic, integrated solution.

Where traditional grey infrastructure might be developed around a key need, NBS by definition should be designed to deliver multiple benefits and takes a more systemic view of the functioning and interdependence of natural systems and processes to maximise co-benefits and avoid negative consequences. As such, NBS typically involve multiple stakeholders and require expertise across a broad range of subjects.

The NBS approach could influence a vast scope of infrastructure of varying sizes: from landscape-scale wetland creation to decontaminating and improving water quality (while providing attractive places for learning and recreation); to green highway bridges reconnecting fragmented ecological networks (while reducing the risk of vehicle wildlife collisions) and urban green roofs to support with air filtration (while providing wellbeing benefits and opportunities for food growing). There is more detail given on this topic in Chapter 3 of this handbook. The specific benefits and co-benefits that an NBS might provide are shaped by the nuances of its geographical location (including ecological, hydrological, and geological factors) and the demographics of the people it might support. However, there are key themes that emerge across successful NBS that can help identify where to focus on mapping stakeholder benefits and potential levers for investment.

Whose business case? Mapping the drivers

Once the need and opportunity are identified, the next step is to understand the drivers of stakeholders who might invest in (and benefit from or be disadvantaged by) an NBS (Figure 6.2). The case for investment largely depends on who is driving the case for the NBS.

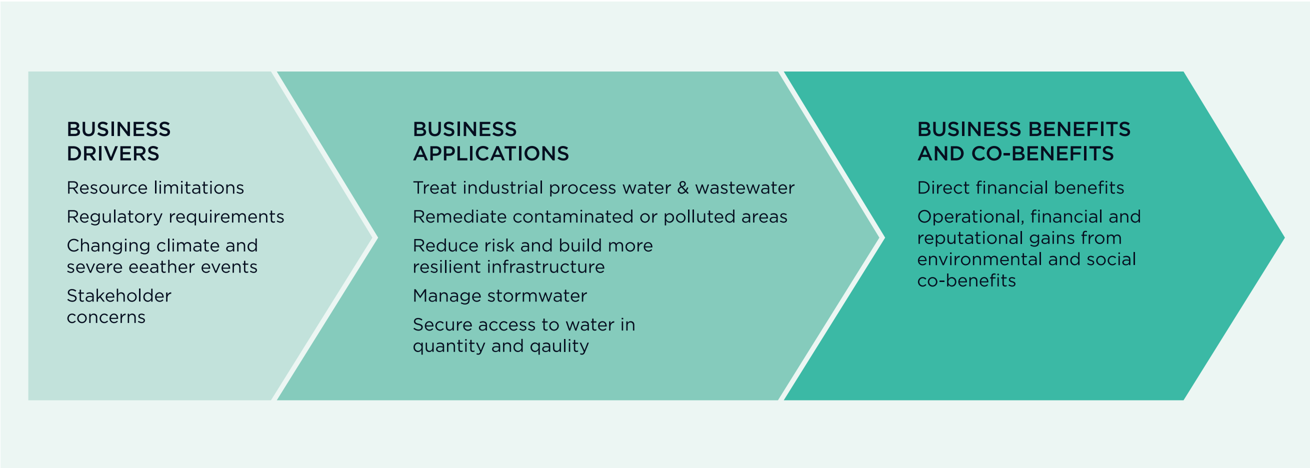


Figure 6.2. Example categories of drivers, applications, benefits, and co-benefits of NBS (WBCSD, 2015)

The opportunity for NBS might be identified and proposed locally, from the local authority or other social or environmental group. The key challenge here might be in making the business case and securing the finances needed (often by seeking out new partnerships) to deliver the NBS. Alternatively, an opportunity for NBS might be identified from a business as a means to avoid operational risk, reduce inefficiencies, secure resource sustainability, or unlock new commercial opportunities. The key challenge (indeed, opportunity) here will be how to work in partnership with additional stakeholders and create partnerships across different sectors to unlock broader benefits and co-benefits.

Locality driven

NBS are often driven by their geographical location meaning that their implementation is led by local authorities, tasked with spatial planning and the delivery of infrastructure. This is to help meet multiple social, environmental, and economic needs of a given region. However, this is framed as 'locality driven' rather than 'public', as in some cases schemes might be proposed by other local interest groups, including local environmental NGO and partnerships (which will often include the local authorities). Drivers might include those listed in Table 6.1.

Table 6.1. Drivers to NBS due to locality

RISK		OPPORTUNITY
PLACE	Averting significant environmental events (e.g. flood)	Environmental cost savings (e.g. cheaper way to clean water)
SOCIAL	Public ill-health	Public health benefits Improve social cohesion
ECONOMIC	Un(der)employment	Job creation New businesses (incl. tourism) Attract inward investment Increase land values
REPUTATIONAL		Build national/international reputation as innovative

Even where there is a clear case for NBS, securing the finance within typically constrained public budgets is a huge challenge (see also section "Notes on public funding and the public toolkit"). Useful resources for further mapping the case for NBS are given in Table 6.2.

Table 6.2. Resources for mapping financing for NBS

RESOURCES FOR MAPPING FINANCING	DESCRIPTION
Natural England: Green Infrastructure – Valuation Tools Assessment www.publications.naturalengland.org.uk/publication/6264318517575680	Review of tools available that aim to value green infrastructure
The Nature Conservancy: A Procurement Guide to Nature Based Solutions www.nrcsolutions.org/wp-content/uploads/2018/02/NBS_Procurement_Guide.pdf	Guide to NBS for communities and public sector
Ecosystem Approach Handbook www.ecosystemsknowledge.net/handbook	Advice for effective partnership working to improve ecosystem services

Business driven

Businesses increasingly understand how their operations depend and impact upon stocks and flows of natural capital. While there is a very broad spectrum of adoption of this approach, the majority of companies are not yet following this approach, but it is a growing trend. Global leaders in sustainability demonstrate there is a clear business case in integrating the natural capital approach. Drivers might include those given in Table 6.3.

Table 6.3. Drivers to NBS through business

RISK		OPPORTUNITY
OPERATIONAL	Manage severe events (e.g. flood, drought) that compromise operational stability Reduce dependence on degrading natural processes and resources Reduce workforce contact with health and safety issues	Improve operational resilience to changing climate and natural environment Healthier, more productive workforce Attract new talent
REGULATORY	Avoid costs of non-compliance	Help shape policy
FINANCIAL	Avoid divestment due to concerns of unsustainability	Environmental cost savings First mover advantage Unlock new markets
REPUTATIONAL (Including corporate social responsibility)	Address stakeholder concerns including environmental, public health, recreation and safety	Social licence to operate Improve brand reputation

If there is a clear business case for corporate investment in NBS, operational capital should be applied for this purpose where available (alternatively external funding might be secured). Even where the numbers make a clear case, there might be institutional pushback to an NBS project. This can be due to resistance to change, lack of understanding of the NBS approach, a short term economical focus for the business i.e. failing to account for the longer term economic benefits of changing to an NBS approach because of an increase in short term outlay, fear associated with the unknown, and lack of internal capability to deliver an NBS scheme.

Useful resources for further mapping the case can be found on the World Business Council for Sustainable Development (WBCSD) initiative including the business case for investment, case studies. and decision-making tools[1].

Drivers for external funders and investors

In many cases, internal capital funding will not be available in full for an NBS scheme and external investment will need to be sought. As such, it is critical to understand potential external financing sources, and what drivers for their investment might be (Figure 6.3). Different sources will look for different forms of return, which has important implications for the management of natural capital.

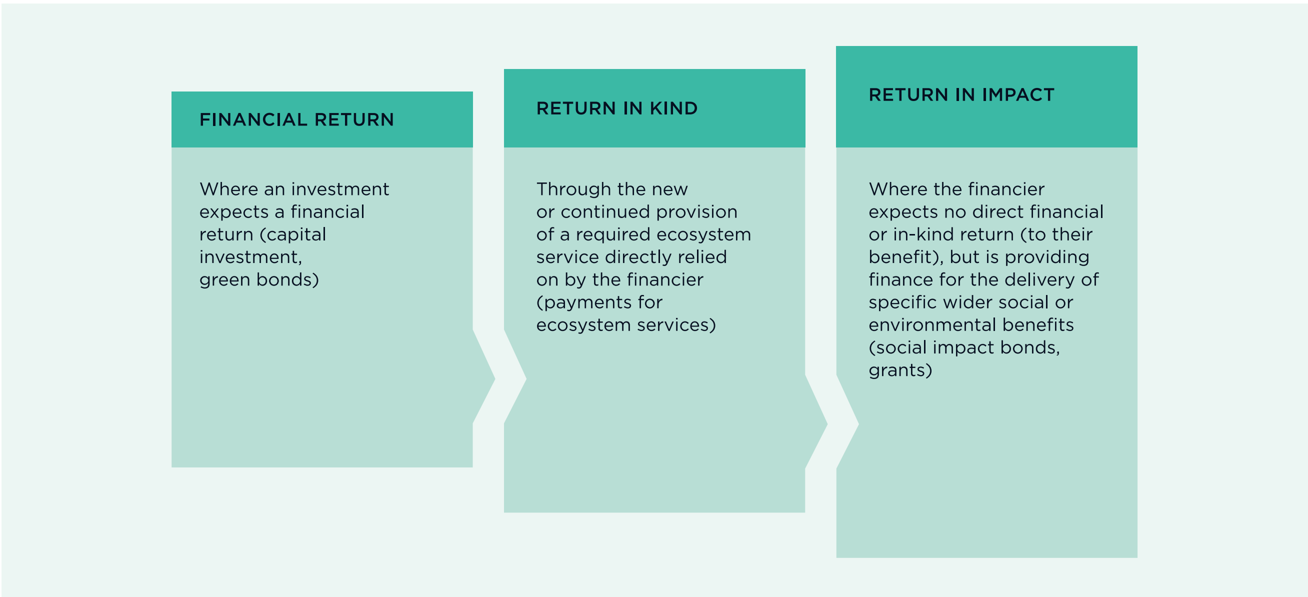


Figure 6.3. Drivers for external investors and funders

A responsible application of the natural capital approach understands that it is not possible – or appropriate – to seek to commodify (and gain a financial return on) all aspects of natural capital. Some forms of natural capital do lend themselves to new financial opportunities (for example, responsible forestry), but it should not

[1] www.naturalinfrastructureforbusiness.org

be the intention to derive financial return from all investments in natural capital.

A sensible approach to this concern is **blended financing**, which secures a combination of the above forms of investment for NBS. There is growing momentum in the development of innovative financial mechanisms for NBS (and more broadly natural capital investment), in the recognition that currently no or few obvious financing streams for NBS exist.

Understanding the stakeholders: winners and losers

Early engagement with stakeholders, including the immediate community, is critical to help develop a sense of co-ownership of the NBS, to shape the NBS to maximise its potential benefits, and to better understand concerns (which can arise from lack of understanding of the scheme as a diversion from traditional schemes). The community is an invaluable source of local information and may suggest design aspects that are not otherwise considered. Some stakeholders might also become co-financers of the NBS.

Whether led from the public or private sector, stakeholders with a material interest (benefit or loss) in an NBS should be mapped to understand the business case. Support – whether financial, political or otherwise – will be required for successful implementation (and its long-term management) of NBS by its material stakeholders.

Often, NBS are funded by multiple stakeholders, or if singularly, with the understanding that there will be multiple beneficiaries with either the intent, or acceptance, that potential benefit to ‘free riders’ (in the case of business competitors) is worth a singular investment as the NBS is of strategic importance. For example, a business that significantly invests in upstream water management is inevitably also benefiting the wider public, and potentially other businesses in the water catchment. It is also most likely deriving greater return on its investment than its traditional grey infrastructure alternative.

Equally, understanding which stakeholders might stand to lose (or perceive that they will lose) is critical in securing social licence to operate by the community where the NBS might be implemented. For example, ‘green gentrification’ is a growing concern where investment in urban green spaces might result in increased property prices that in turn can drive out extant communities who can no longer afford to reside there and thus reduce the value of the NBS by failing to provide a social benefit to those who would most value from it.

Making the case for NBS

Once the need, opportunity, and their drivers are identified, the next stage is to build a clear case for investment. This will invariably involve cost-benefit analysis and will rely on effective interpretation of evidence. The **natural capital approach** is an important framework for this (discussed in the following section). When developing a business case for NBS, it is important that the following be considered in the preparation of the budget, to ensure that sufficient resources are allocated to the implementation and maintenance of the NBS:

Right expertise: NBS thanks to their nature of delivering multiple benefits, require interdisciplinary expertise. For example, expertise in areas such as ecology, hydrology, and environmental science, alongside social scientists, public health practitioners, engineers, and planners – among others – will need to input into the project design and delivery to ensure it is most effective. Where the NBS presents a diversion from business-as-usual, it is likely that the required expertise may be external, and perhaps best sought through partnership working. Expertise from environmental economists and accountants is recommended for the preparation of natural capital accounts to support in decision making.

Lifecycle costs: The full lifecycle costs of an NBS should be considered, including implementation, permitting, operational, and maintenance costs. In many cases the full lifecycle cost of NBS is less than the traditional alternative, but there may be a higher initial outlay. Furthermore, there is usually (depending on the nature of the NBS) a delay before it is fully functional (for example, while plants grow and ecosystems develop), and the functionality will often continue to improve over time (i.e. as ecosystem function, for example biodiversity, strengthens). Although the maintenance costs of NBS are often lower than their grey infrastructure alternatives, in practice it is often perceived to be even lower than it actually is, and several NBS schemes fall into disrepair or sub-optimal functioning.

Access to land: Depending on the nature of the NBS, the scheme may require substantially more land (for example, in the creation of a new wetland) than its grey infrastructure alternative. If this is the case, due consideration is needed for potential land acquisition, new partnership agreements, and the potential role of local designations, conservation covenants, and community land trusts.

Optimising co-benefits: Depending on the nature of the NBS, it may also be beneficial to identify factors that will optimise co-benefits. Such efforts might include an additional upfront cost, but could yield multiplied benefits (or reduce risk). For example, a public engagement campaign to help inform public users of the benefits of an NBS could help prevent unintended destruction of an NBS through lack of understanding and gain zpartners or communities, as well as potentially identifying further co-benefits.

The natural capital approach

The benefits we derive from the natural environment have historically been poorly understood and taken for granted. The environmental impacts of economic activity have largely been treated as externalities, with the result that organisations have not taken responsibility for these wider costs to society – or understood how their own sustainability depends upon more responsible stewardship of natural resources.

In recent years there have been increased efforts to understand, quantify, and internalise these costs and benefits. The natural capital approach considers our natural assets as capital 'stocks' and the 'flows' of benefits that we derive from them, also known as ecosystem services. It is important to consider both stocks and flows to ensure we are not running down nature's account unsustainably – that is, taking more (and faster) than can be naturally replenished, or crossing natural thresholds and limits of change.

Making the case for investment in NBS will likely involve an element of natural capital accounting to help demonstrate cost-benefit and return on investment. Natural capital accounting maps and quantifies, within a defined boundary, stocks of natural capital and the multiple benefits that we derive from them. Such accounts can be developed on the city or even national scale, for a business's operations or a product.

Sometimes highlighting a benefit or dependency that was not previously recognised might be sufficient to build a case. However, quantifying this in some form is often required to demonstrate the cost effectiveness of investing in natural capital (through an NBS) versus business-as-usual (whether 'do nothing' or a traditional grey infrastructure alternative). There are broadly three approaches to valuation:

a) Qualitative:
Evidencing value through expert opinion and surveys with stakeholders.

b) Quantitative:
Quantifying value through demonstrating change, for example in air quality.

c) Financial:
Ascribing financial values to natural capital stocks and flows. There are several methods, including: production-function, which identifies the value of natural capital to commercial processes; replacement-cost, which ascribes a value based on the cost of man-made infrastructure to provide an equivalent service; and willingness-to-pay, which determines a value based on the extent to which stakeholders might pay for nature's services.

While very appealing from an accounting perspective, there are some drawbacks.

These are mainly:

a) Many are concerned that financial valuation effectively defines nature as a commodity;

b) Due to the complexity of natural systems, there is a huge variance of suggested valuations emerging in academic literature; and

c) Such values are not necessarily convincing to budget holders while they are not material, chargeable costs.

Further tools and resources include those given in table 6.4.

Table 6.4: Tools and resources to help drive NBS

RESOURCE	DESCRIPTION
Natural Capital Protocol www.wbcsd.org/Programs/Redefining-Value/Business-Decision-Making/Measurement-Valuation/Natural-Capital-Protocol	Business-led standardised approach to the consideration of how a business depends and impacts on the natural environment, and how to integrate such dependencies into enterprise accounting and risk management processes
Natural Capital Coalition www.naturalcapitalcoalition.org	International collaboration that unites the global natural capital community
System of Environmental Economic Accounting www.seea.un.org	UN led framework to integrate economic and environmental data to provide a more comprehensive and multipurpose view of interrelationships. Contacts internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics and accounts
WAVES Partnership www.wavespartnership.org	World Bank led global partnership promoting sustainable development by ensuring that natural resources are mainstreamed in development planning and national economic accounts

Notes on public funding and the public toolkit

A key limitation to the mainstreaming of NBS is the lack of specific funding specifically for NBS. Therefore, it is key to first identify potential sources of funding, and then to articulate the benefits that an NBS scheme can offer multiple funders.

A particular challenge is that public funds are usually routed (and prioritised politically) towards social infrastructure, and are often insufficient to cover all social infrastructure needs let alone environmental projects. It is important to articulate the multifunctional benefits of NBS – and to this end their socio-economic benefits in particular. This is to make it clear that this is not a dispute between public spending for social or the environment, but offers an intelligent, holistic solution of both social and environmental benefit. This will help break through silo gaps and can alleviate the root causes of a myriad of modern issues and needs. For example, the benefits of green space for health, wellbeing, and social cohesion are well understood. Therefore, investment in urban parks should be articulated not only in terms of its benefits to drainage, urban cooling, and biodiversity, but also wellbeing, cohesion, and potentially productivity benefits through food growing and other enterprises such as the benefits of greening a city, thus making it more attractive and increasing investment in the area.

Beyond the challenge of securing funding, the (local) public sector has a key role in setting protections and incentives (for free) through policy and taxation mechanisms to help create the right market conditions to encourage the establishment of NBS schemes. This will help to further the case for NBS schemes whilst enhancing the locality, in turn bringing about more internal investment.

Strengthening the case

Working in partnership to develop, implement, and maintain NBS will likely enable benefits to go a lot further, potentially reduce costs (through economies of scale), and generally increase the success of an NBS. Joining the NBS schemes in a region together can be a much more effective use of resources. In some cases, there may be multiple investments for environmental enhancement in the same area that would be significantly more beneficial (and cost-effective) if aligned following the principles of the ecosystem approach (Figure 6.4).

Figure 6.4. The different drivers of NBS and how to manage them

6.2 Economic Risks

Economic risk from an NBS project will vary with the type of solution, targeted resilience outcome, level of investment, scale of actions, and the lifespan of the NBS. Performance measures of an NBS will vary with time and scale, leading to shifts in the level of resilience, and therefore risk mitigation of time. This can represent an improvement or deterioration in performance over time. The level of acceptable risk will be affected by the level of return on investment. This is often difficult to distinguish for NBS, with significant benefits often not quantified, monetized monetised, or included in the business case or risk-return performance analysis.

What type of economic risks can be addressed through NBS?

The economic risks alleviated by NBS can be those associated with; **food security**, **water security**, **disaster risk reduction**, **human health**, and the potential economic **impacts of climate change**. The issue of climate change brings with it economic risks, known and unknown, so the potential for resilience and adaptation of NBS is crucial. The unknowns of climate change make the necessary resilience of NBS a moving target as they can alter ecosystems and their associated services. Ideally, NBS should offer a solution for a broad range of potential climate outcomes. Resilience measures for adaptation to climate change are varied, and can be those to mitigate detrimental changes, flood damage, heat island effects, long-term health, and well-being.

• There is a recognised potential for improved resilience which reduces costs to the local community and government from the impacts of moderate to extreme events.

• Green spaces are multifunctional - trees can reduce heat island effects, and provide social spaces for promoting physical and mental health.

• Improved air quality and visual landscapes provides opportunities for improving health and well-being within communities and create reasons for business relocation and investment in an area.

Who do these risks impact?

NBS approaches have the potential to be cost-effective; they can help address resource limitations and increase resilience and adaptation to a changing climate when compared with grey infrastructure. They can also bring co-benefits such as those shown in Figure 6.5.

Groups and individuals affected either through investing in resilience or rebuilding after events are:

- All levels of government (local, regional, national)
- Local communities (homeowners, councils, farmers)
- Business enterprises (business, insurance companies, councils, investors)
- Local and regional economies

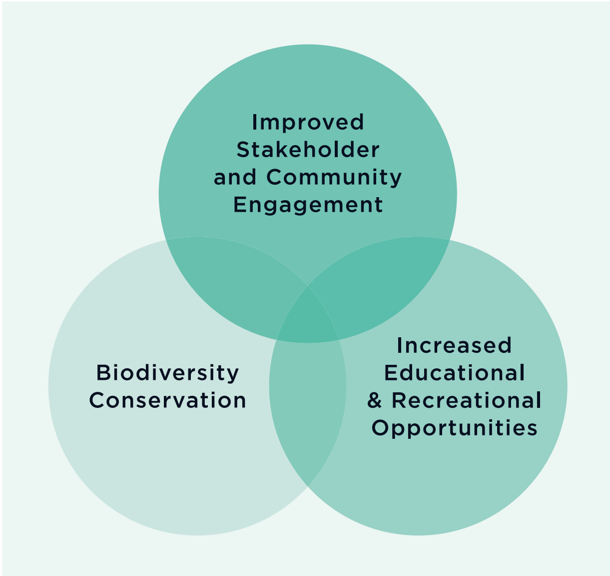


Figure 6.5 Venn diagram showing the potential co-benefits of NBS

How does NBS mitigate these?

Multifunctionality, the capacity to produce several services simultaneously in a single area, is the most important character of NBS compared with hard or grey infrastructure.

This mitigation is achieved through:

- Using natural solutions that can deliver multiple co-benefits
- Providing alternate pathways to investment over various scales and timelines, combatting path dependence
- Creating opportunities for community involvement, ownership, and investment: citizen science is a powerful tool for engaging people in their local area and driving forward necessary changes and improvements
- Acting as an enabler to provide partnership opportunities between a variety of stakeholders, e.g. government-business (PPP), B2B-B2C, community-business-local government

How can these be assessed and included in a business case?

There are several tools that can be utilised to assess the impacts of an NBS. The NBS Business Model Canvas (BMC) facilitates capacity building and is supported by a comprehensive guidebook with multiple case-studies. The NBS BMC enables the clear identification of key stakeholders to involve and how they can be engaged through different governance models.

Defining the NBS business case is often problematic. There is an opportunity to create a structure, model, or framework in which co-benefits and multifunctional attributes of NBS are identified, captured, realised, or understood. The following framework has been devised as part of the ThinkNature project (Coles et al., 2019) and is based on the key elements of a hierarchy of steps/framework. This involves a two-step NBS project initiation phases namely SITE4NBS evaluation framework that is followed by a more detailed analysis using the RISE4NBS concept (Figures 6.6 and 6.8 and Table 6.5). Valuing nature and the contributions it makes to climate change adaptation, resilience, or mitigation requires the re-designing of classical business models. This is to create fit for purpose nature-based solutions that will mobilise finance for sustainability investment creating pathways for direct action.

Creating this framework provides a workspace to allow for the development of a number of facilitation mechanisms such as:

- understanding scale and integration of diverse elements that may fall outside individual projects
- strategies for the long-term maintenance of NBS
- the engagement of alternate stakeholders and co-beneficiaries
- promoting the inclusion of recognised standards for NBS.

In endorsing these tools, it is recognised that strong advocacy is often required, typically thorough a dedicated co-ordinator who will act as a facilitator between interested parties or provide opportunities to engage a wider stakeholder group.

This evaluation can be incorporated into a simple high-level process matrix that provides a preliminary framework for any project. By starting with a very broad strategic view, the co-planning, niche innovations, and other stakeholders can be identified. These elements are in part derived from Raymond et al. (2017a; 2017b) and act as an enabling framework for proponents and communities to build their projects and identify knowledge, skills, policy, and financial gaps and develop natural capital accounts. This is done using key performance indicators, while also collecting data and providing performance feedback loops.

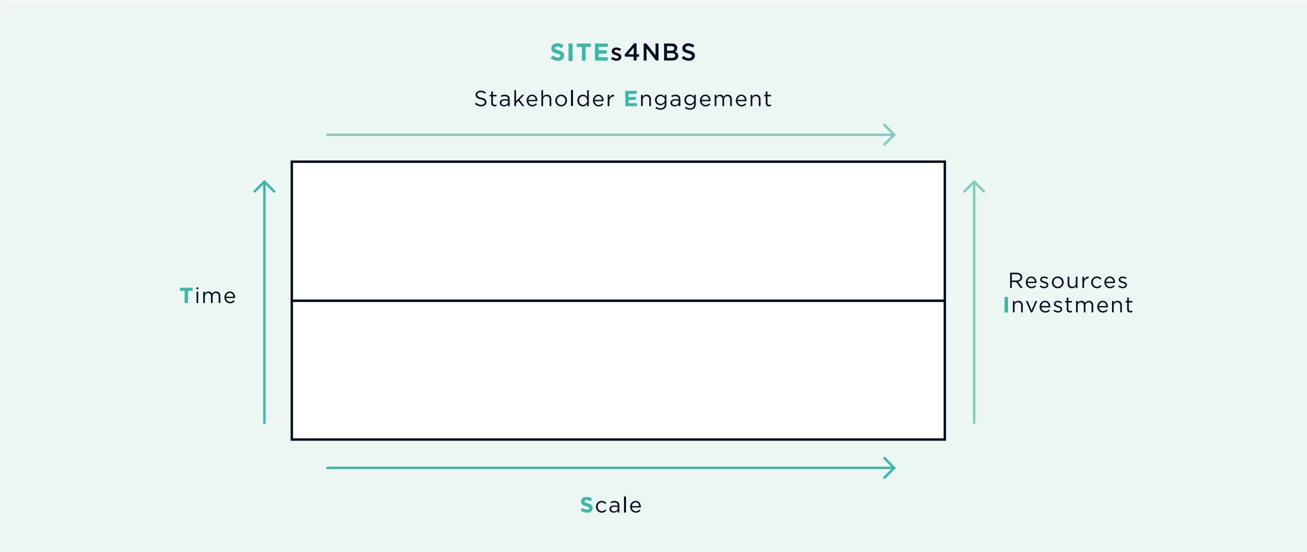


Figure 6.6. SITEs4NBS analytical framework that conceptually identifies: a) Scale of project; b) Type of Investment; Time required; and level of stakeholder Engagement

This approach provides the opportunity to evaluate each segment of the proposed project for both internal and external partners, beneficiaries, and resource providers, and determine the potential for staged or phased approaches to investment and implementation. The high-level matrix SITE4NBS framework (or strategic case) feeds into the second integrative evaluation framework RISE4NBS, which uses integrating tools such as Risk Analysis, Investment Focus, Stakeholders-Beneficiaries, and Environmental-Socio-economic co-benefits, amongst others.

RISE4NBS utilises the SITE4NBS high-level framework to plan the strategic engagement and NBS project design that includes the identified potential stakeholders, resource, and financial options. These are linked with the maintenance, monitoring, and co-benefits that accrue over time through the stages of the project(s). Including:

1. Design NBS implementation processes;
2. Implement NBS;
3. Potential transfer and upscale NBS (financial opportunity); and
4. Monitor and evaluate co-benefits across all stages (and collect data on performance)

In utilising the high-level matrix or evaluation framework we can arrive at the pre-implementation phase with a knowledge of the scale, timeframe, cost, identified beneficiaries & stakeholders, funding gaps, investor options for potential phases, and worked business Model Canvases for each element of the project. We suggest using the RISE4NBS strategic framework and business case modelling (Figure 6.8) to assess the elements of the NBS project, including the following shown in Figure 6.7.

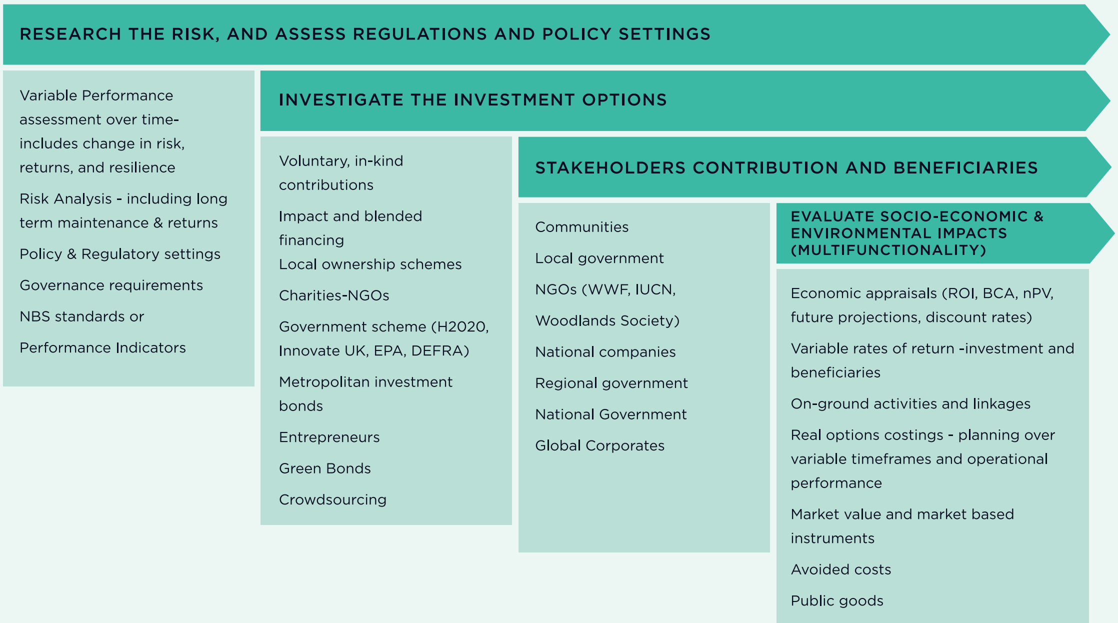


Figure 6.7 The elements of an NBS project.

INTEGRATIVE ELEMENTS OF A STRATEGIC BUSINESS CASE FOR NBS (RISE4NBS)

Risk Analysis-

(performance, ecoservices, governance, standards, maintaining, barriers, drivers, LCC)

Investment Options-

(sectors, blending, avoided cost, returns-incentives, regulation, value creation-capture)

Stakeholder Collaboration

(individuals, communities, charities, business, governments, NGOs)

Environmental-Socio-Economic

(co-benefits, capacity, skills, services, linkage, multifunctionality)

Adapted from Raymond et al, 2017. Environmental Science & Policy doi: https://doi.org/10.1016/j.envsci.2017.07.008.

Figure 6.8 Evaluating the integrative elements of the strategic business case for NBS using the RISE4NBS strategic framework and conceptual NBS business case.

How do they change with each type of NBS?

The risks and impacts of an NBS will vary according to the level of intervention and the type of NBS that is implemented. These impacts are dependent on time (e.g. 2, 5, 10, 30 years) and scale (e.g. m2, ha, km2) of the solution. Built infrastructure (i.e. green walls, etc.) will have different risk/return values than managed ecosystems (i.e. wetlands, forests).

Table 6.5 Some of the elements to be considered assessed under the SITEs4NBS analytical framework.

LEVEL OF ACTIONS OR ACTIVITIES	STAKEHOLDER AND COMMUNITY ENGAGEMENT	FINANCIAL INVESTMENT OR RESOURCES REQUIREMENT	TIME REQUIRED TO DELIVER SOLUTIONS (SINGLE OR MULTIPLE)	VARIABILITY ON THE SCALE OF THE PROJECT
Individual to groups	Individuals Small action groups Small business	Voluntary in-kind Local fund raising Business - community support (local ownership schemes) crowdsourcing	Short • Days • Weeks •Months	Square metres (Wall/Roof)
Local Community	Local business Local action groups Communities Charities	Local council and municipal grants (local green spaces, local flood management) Crowdsourcing	Short • Weeks • Months • Years	Hectares (green space, parks) Square kilometres (woodlands, wetlands, flood management schemes)
Regional	Cities (C40, ICLEI, R100) Counties, District Councils; Companies; Regional and National Governments Charities NGOs	Regional grant schemes (Charities, regional flood management schemes National grants schemes (governments, entrepreneurs metropolitan investment bonds,)	Medium • Months • 1-3 years • 3-5 years • >5 years	Stream-River Catchments (wetlands, bogs, peatlands, leaky dams, water storages, flood and drought management schemes, resilience planning, national parks and open spaces).
Global	Cities (C40, ICLEI, R100) National Governments States Corporations NGOs	Global investment options (Green Bonds, blended finance, impact finance, Debt based finance)	Long • 5-10 years • 10-20 years • 20-50 years • >50	Actions on Climate change. (Mitigation and adaptation through national initiatives). SDGs (Supporting, linking, delivering)

Performance risks of different types of NBS

The risk and performance measures will vary between types of NBS and will require understanding of the risk to be addressed, the type of NBS implemented, and the scale of the NBS. There is limited performance data available for integrated NBS, although system performance data can be elicited or extrapolated from known performance criteria – say for a pocket park, flood mitigation basin, or natural wetlands.

6.3 Financial Instruments

The ways natural infrastructure/nature-based solutions are financed is a key consideration. In most cases NBS are financed either by municipalities, regional authorities and national governments (public stakeholders), or by private companies and philanthropic organisations. The process of securing finances varies significantly across states and regions as well as public and private entities. In many cases, financing can take a variety of forms depending on the local context and the will of the stakeholder to collaborate (WBCSD, 2017). Figure 6.9 shows different financing opportunities:

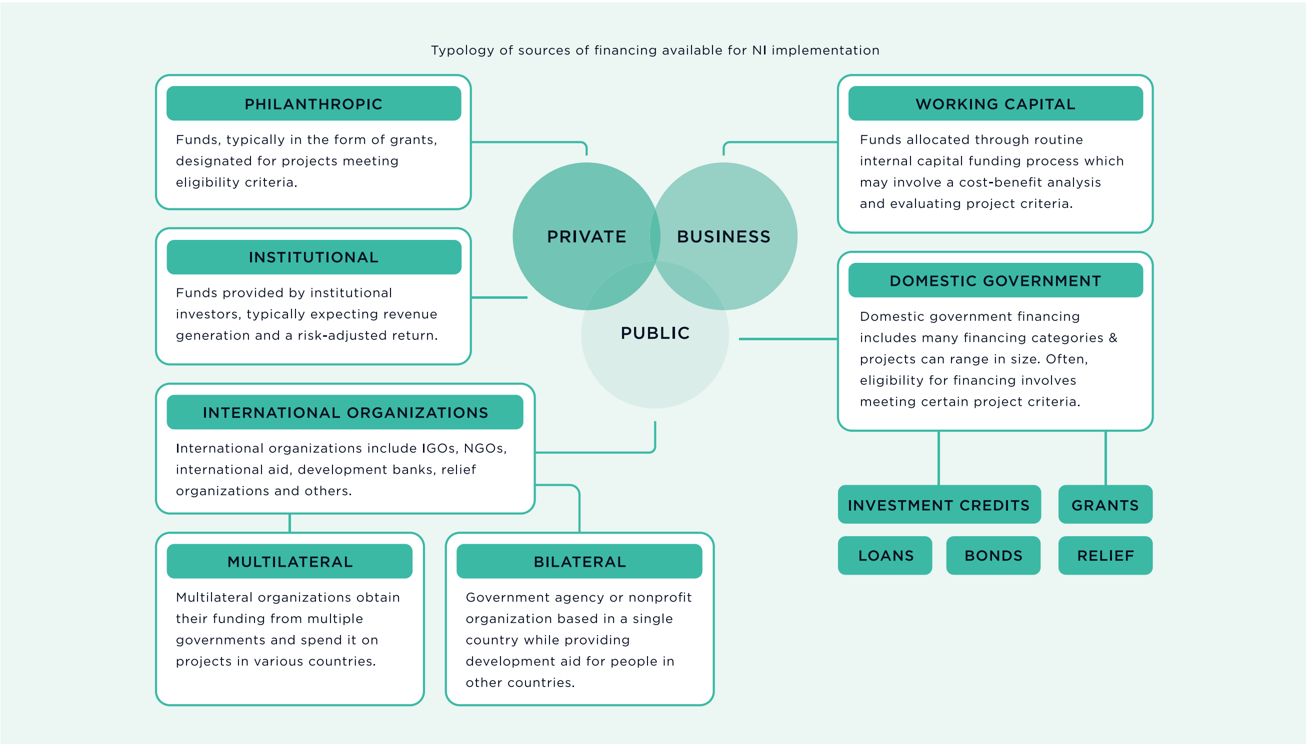


Figure 6.9. Typology of sources of financing available for NI implementation (WBCSD, 2017, p. 21)

The following sections in the sub-chapter are largely based on the categorisation of financing approaches developed in the framework of the Horizon 2020 project GrowGreen (Trinomics & IUCN, 2019). This document covers most of the existing financial instruments for NBS projects that could be used by both public and private entities. Since our main focus is on cities, the following categorisation of financing mechanisms starts from the premise that a municipality has two main options for increasing NBS in the city:

1) Implement NBS projects or maintain existing NBS directly (especially on municipality-owned land); in this situation, the municipality pays for the intervention, either through funds it already has or by obtaining loans and revenues to finance the project (Trinomics & IUCN, 2019).

2) Encourage other actors (e.g. residents, utilities, businesses) to implement NBS (especially on their private property) or to contribute to the maintenance of existing NBS in the public domain; in this case, the local authorities provide incentives to other stakeholders, or stimulate private finance by other means (Trinomics & IUCN, 2019).

Instruments used by public entities

All the infrastructure services require an adequate stream of financing over the long period of time to ensure their sustainability and quality. In general, public funds usually come from three main sources such as tariffs (users paying for specific services), taxes (a source that comes from the government and can be used to finance different kinds of services within its jurisdiction) and transfers (a city can receive a transfer from a federal government or a development agency to use the money for a specific purpose) (Browder et al., 2019).

The types of instruments that will be explored here include the following instruments used by public entities (Trinomics & IUCN, 2019):

- **Use of public budgets**, such as pooling funding from different government departments or making use of previously untapped sources such as the public health budget.
- **Grant funding and donations**, including: EU funding; , grants from regional and national public bodies; , philanthropic contributions; , and crowd funding.
- **'Green finance'** (or debt-based instruments): loans from public or private financial institutions; , green bonds; , and the Natural Capital Financing Facility (NCFF).

Use of Public Budgets
NBS project are often funded from local authorities' own budgets. Even though there are some examples of national budget for NBS/ Green Infrastructure (e.g. PES in Peru), budgets dedicated specifically for nature are usually insufficient. A solution might

be channelling funding from different municipal departments. Cities could pool funding from different departments within the city administration or other sectors to deliver NBS projects with cross-sectoral benefits. For example, cities could pool funding for a specific purpose, which can be linked to health, energy efficiency, or safety. The important thing is to align design and planning of NBS in such a way that would help different departments to achieve their core objectives. Currently, it is recognised that both public health and crime prevention are improved by green infrastructure development but research is limited into these and other areas for collaboration, for example food production and educational opportunities.

Example - Natural Choices for Health and Wellbeing programme, Liverpool, UK – Funded by the Liverpool Primary Care Trust, the programme aimed to reduce inequality in health and wellbeing, increase engagement with the natural environment, and provide opportunities for disadvantaged people (Drayson & Newey, 2014).

Grant funding and donations

Public stakeholders can access funding for NBS projects from external grants. The most obvious funds are listed below (Trinomics & IUCN, 2019):

a) European Structural and Investment Funds (ESIF): present several opportunities to finance GI projects, including in urban areas. Within ESIF, the Cohesion Fund and the European Regional Development Fund (including INTERREG for transnational projects) are most suitable for urban GI.

b) Programme for the Environment and Climate Action (LIFE): provides co-funding for projects in the area of the environment (including nature and biodiversity) and climate change adaptation and mitigation.

c) Horizon 2020: the EU Framework Programme for Research and Innovation can support NBS projects with an innovation or research component

d) Regional and national government grants: local authorities may access grants for environmental projects - including GI - provided by upper levels of government

e) Philanthropic contributions: GI projects have traditionally relied on charitable contributions from foundations, citizens, private sector donors, etc.

f) Crowdfunding: raising funds for a project (usually of public interest) through the donation of small amounts from a large number of individuals. Suitable especially for supporting small-scale projects that are not necessarily suitable for other financing instruments.

An example of a grant-funding scheme is the Horizon2020 programme that is financed by the European Commission. Currently, the programme funds many projects that focus on research, innovation, and scalability of NBS in Europe and globally.

Natural Capital Financing Facility (NCFF)

The financing facility set up by the European Commission and the European Investment Bank (EIB) is a dedicated programme to support conservation and nature-based solutions projects. The projects funded under NCFF should contribute to biodiversity enhancement and climate change adaptation. The NCFF provides funding in two main ways: direct lending or setting up intermediated structures (such as funds or credit lines) via a financial intermediary. The facility is currently in a pilot phase and can sign projects until the end of 2021 (EC & EIB, 2019).

Example - Green infrastructure for urban resilience in Athens: The NCFF loan will finance and support the integration of green components into the restoration of public squares and streets, create green corridors between greened areas, and contribute to the natural restoration of Athens's second landmark hill after the Acropolis, Lycabettus hill. Thus, reducing urban heat islands, increasing water infiltration, and increasing the attractiveness of project areas (EC & EIB, 2019).

Types of instruments used by private entities
Private finance for NBS covers a variety of financial sources such as commercial finance, private companies, as well as the insurance sector.

Types of instruments that can encourage private sector stakeholders to take part in financing NBS (Trinomics & IUCN, 2019):

- **Market-based instruments:** user charges, taxes (as incentives rather than a cost-recovery mechanism), subsidies, tax rebates, credit-trading systems, offsets for residual impacts on biodiversity/GI, and payments for ecosystem services (PES).
- Developing **'Business Improvement Districts'** (BID)
- Creating **Public-Private Partnerships**
- **Regulation and planning standard**

Market-based instruments
One of the examples of market-based instruments is a scheme called Payments for Ecosystem Services (PES). The logic of PES is that a private entity pays money to landowners or farmers to take certain actions to manage their land or watershed in order to provide specific ecosystem services such as provision of clean water.

An example of a PES scheme could be a hydropower company that faces major costs due to upstream riverbank erosion where sediments in the water are damaging equipment and reducing operational efficiency. One of the solutions might be planting vegetation in the river's catchment area that would stabilise the soil and prevent erosion. This can be done in collaboration with stakeholders that own the land in the catchment area such as farmers or regional authorities. So, the hydropower company can pay the farmers for halting their activities adjacent to the river and engage them in planting trees and managing the habitat in a way that would help the company to achieve the water quality objectives (EC & EIB, 2019).

Business Improvement Districts (BID)
It is an initiative of businesses that operate in one area (district) to make the local area more attractive to people

and the businesses. However, they require several businesses within a certain area to be willing to pay for similar services (Trinomics & IUCN, 2019). Companies, as well as other stakeholders, pool the finance by paying an additional levy, which goes directly to the BID management body. This body runs a variety of projects in the local area that can support different kinds of services such as safety and sanitation but also creation of greenery and its maintenance (Merk et al., 2012). BID characteristics are that they are:

- Long-term and sustainable financial source for the local area,
- Provide a strong collective voice,
- Locally driven initiatives that ensures a sense of ownership and local decision-making,

3. Public-Private Partnership (PPP)
PPP is mostly suitable for projects that deliver an attractive return to a private entity, for example, reducing the O&M costs, generating a profit, or providing other benefits that are essential for a private entity. PPP can be defined as "long-term contracts between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility" (Kamiya & Zhang, 2017).

Example: An interesting example of a PPP scheme is the LIFE Elia project, which aimed at applying innovative vegetation management techniques to create ecological corridors along the routes of the high voltage lines in the forests of Belgium and France. It involved project-level stakeholder engagement in the form of a co-creation by the Transmission System Operators (TSO) and the Non-Governmental Organisations (NGO) to innovate the vegetation management of the TSO. The project was provided with a budget of 3 million euros and was co-financed by the European Commission (36.60%), the Walloon Regional government (25.60%), Elia (24.00%), and RTE (13.8 %). The interesting return for these two companies was that by implementing the new management approach they could save on the O&M. Innovative vegetation management method leads to a significantly shorter time for costs to break even, between 3 to 9 years. Furthermore, it would be 1.4 to 3.9 times cheaper than traditional vegetation management (rotary slashing) after 30 years.

4. Regulation and planning standard
Regulation and planning standards are not financial instruments to finance NBS but could incentivise and trigger authorities, and trigger GI implementation by private stakeholders, such as infrastructure developers and homeowners (Trinomics & IUCN, 2019).

The city of Basel in Switzerland is purported to have the highest per-capita area of green roofs in the world. The use of green roofs has been stimulated by a combination of financial incentives and building regulations. Building regulations have required the use of vegetation on roofs since their implementation in 2002. Initiatives aiming to increase the provision of green roofs in Basel were initially driven by energy-saving programmes, and subsequently by biodiversity conservation. In 2002, an amendment to the Building and Construction Law of the City of Basel was passed which defined that all new and renovated flat roofs must be greened. This law was also associated with guidelines defining some basic principles for green roofs (Kazmierczak & Carter, 2010).

- The growing medium should be native regional soils - the regulation recommends consulting a horticulturalist;
- The growing medium should be at least 10 cm deep;
- Mounds 30cm high and 3m wide should be provided as habitat for invertebrates;
- Vegetation should be a mix of native plant species, characteristic to Basel.
- Green roofs on flat roofs over 1,000m² must involve consultation with the city's green roof expert during design and construction.

Other ideas for the future NBS financing

Blockchain inherent characteristics such as immutability and transparency can contribute to further unlocking private capital into Nature Based Solutions. This is especially relevant in the emerging market context where project governance raises significant concerns and deters additional capital from being deployed. For instance, using Smart Contracts to code the drawdown of funds against pre-defined project milestones can act as a powerful layer of assurance for investors.

In addition, NBS relies on being able to capture the financial and non-financial benefits that a project can deliver. Monetising the latter is quite a challenging aspect and currently hinders a wider adoption of this type of nature-based solutions. Similar to crowdfunding, tokenising assets in blockchain can assist in making the project more fundable precisely by reaching out to those investors that can benefit the most (even from a non-monetary perspective) out of the implementation of the NBS project.

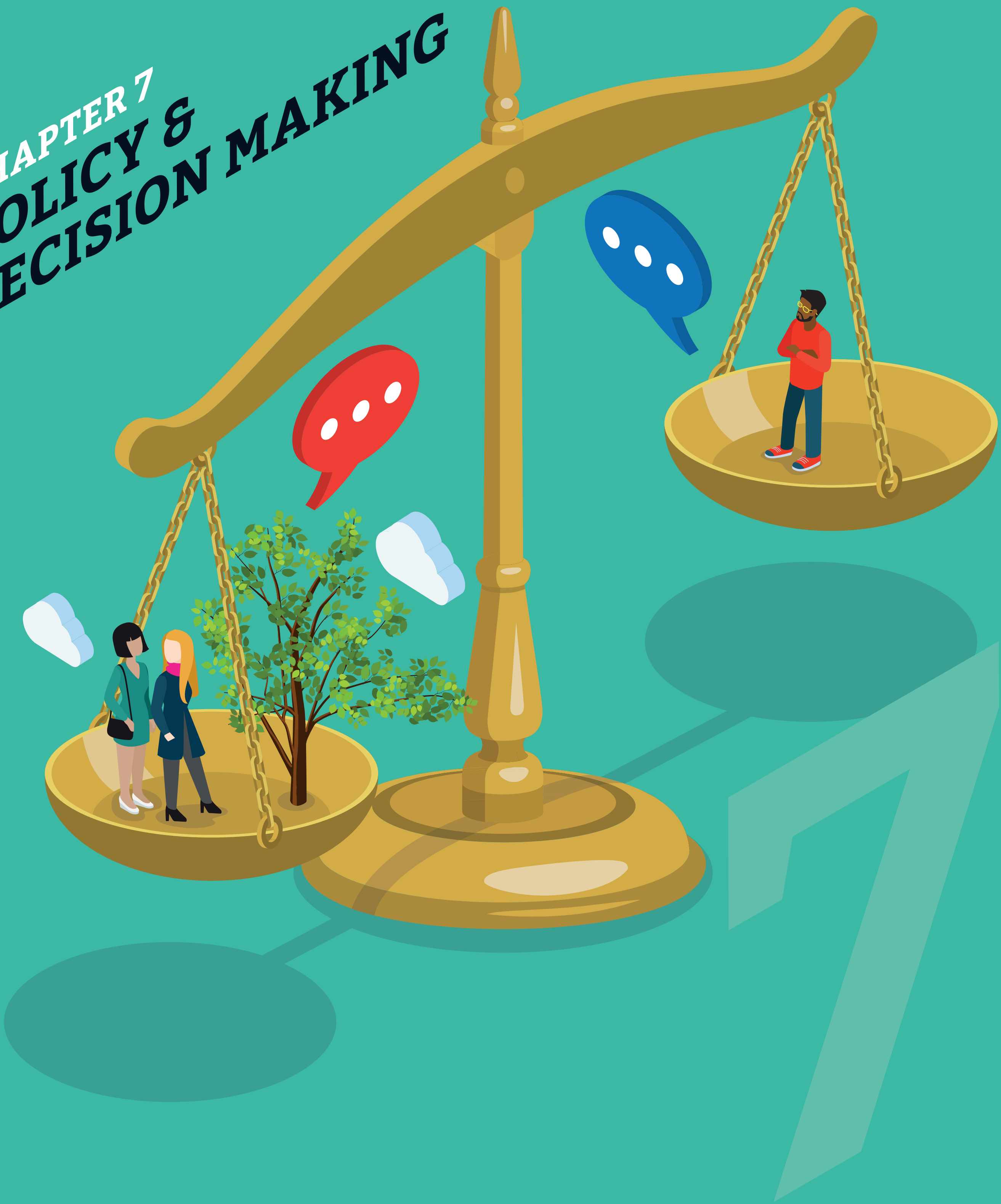
On Developing Impact Bonds

Here we are referring to a type of blended finance scheme that again tries to map the benefit creation by project stakeholder and bring them into a funding scheme. Under this framework, funds will only be provided once a pre-defined measure indicator meets a certain threshold or impact. This measurement should be verified by an independent third-party.

Impact investors will provide the upfront capital to develop the NBS project and outcome payers will only disperse the money, and hence pay back investors, once it meets its impact targets. Contractually this is quite complex to articulate, but it certainly aligns all parties involved towards achieving the intended project outcome.

CHAPTER 7

POLICY & DECISION MAKING



7 POLICY & DECISION MAKING

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NBS can be seen as a flagship term meant to increase consideration of nature in public policy (EC, 2015; Eggermont et al., 2015). In this chapter, policy is defined as an organised system of targets and principles, guiding decisions to achieve the desired outcomes. A policy may express goals, values, intents, as well as actions to achieve the goals. NBS can and should be included in several policies (health policy, safety and security policy, development policy, energy efficiency, etc.). The strongest way to promote NBS is to include them in all relevant policies, as well as promote specific NBS-related policies and regulations at different levels (municipal, county, national, EU). Decision-making results in the development of policies and can be part of the implementation process of a policy too. An effective decision-making mechanism should allow informed, transparent, and ethical decisions, supporting sustainable development. The focus of this chapter is on both policies and decision-making mechanisms regarding NBS.

7.1 Policy and legislation drivers

There are various barriers that can hamper the proliferation of NBS. However, a rich set of drivers can also be created to overcome barriers and to promote NBS planning and implementation. In the ThinkNature project, the **driver-barrier landscape of NBS** has been investigated (Bernardi et al., 2019) and policy barriers and drivers came up as the most frequently mentioned (Figure 7.1), suggesting that policy issues are fundamental in the formation of the driver-barrier landscape for NBS. The main finding was that there are no single solutions with regards to the development of policies, but all relevant policies should be streamlined to support NBS. The key to change is to support new ways of comprehensive thinking with regards to the policy instruments.

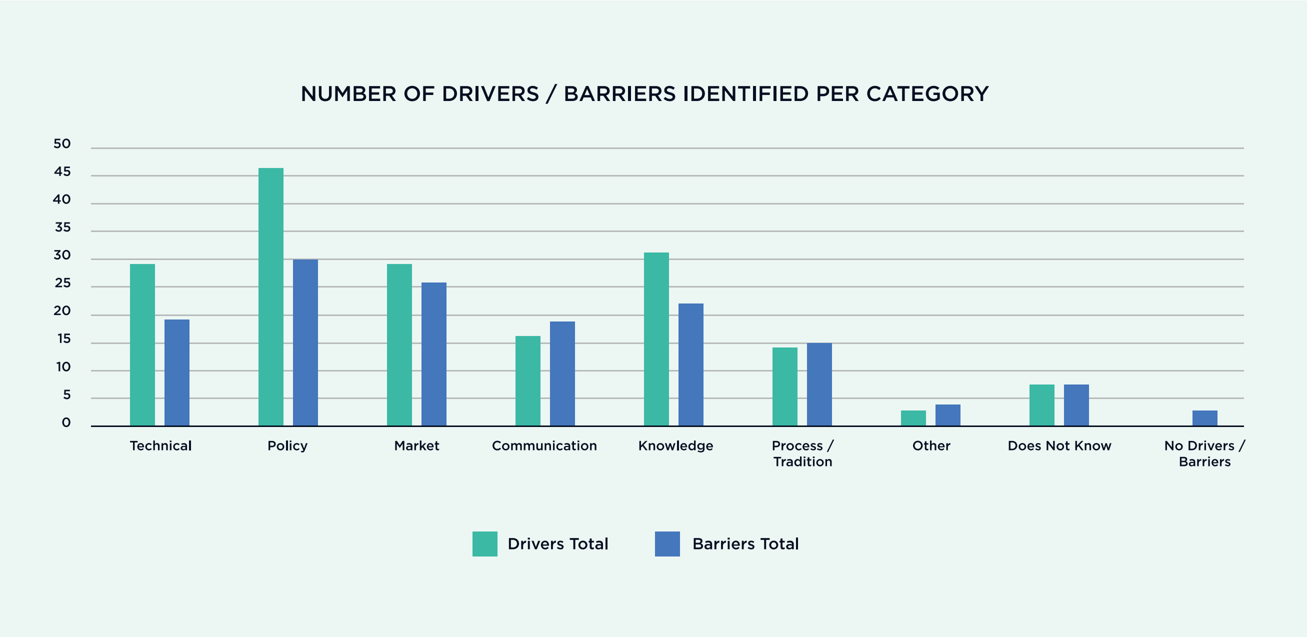

Figure 7.1. Number of drivers and barriers towards the implementation of NBS from the ThinkNature project's survey (Bernardi et al., 2019)

While barriers and drivers for NBS are context- and place-specific, there can still be solutions at various levels from local guidelines to national regulation, as well as EU strategies and directives (Table 7.1). Long-term policies are necessary to support long-term investment, research, monitoring of functionality of NBS, and product development. Furthermore, coercive regulation together with active enforcement of it are needed to make sure that NBS will become a part of everyday infrastructure. Without forceful regulation, the implementation is often left aside, uncompleted, or has minimal input. In general, multiple policy instruments, both 'carrots and sticks', are needed to promote NBS: EU, national and municipal level policies, coercive legislation, guidelines, instructions and recommendations, concrete local strategies (e.g. storm water management strategy, green roof strategy, etc.) and plans (e.g. woodland plan), as well as monitoring and evaluation systems for updating policies. As NBS is still an evolving concept, policies should create positive stimuli, and good practices should be effectively disseminated. Specifically, policies should promote NBS and the implications of the upper-level policies for the local-level should be clearly explicated.

Table 7.1. Summary of policy drivers and examples of possible actions at various regional levels

DRIVERS / ACTIONS	LOCAL	NATIONAL	EU
Create a wide toolkit of policy instruments	Assess the possibilities of coercive norms and voluntary actions: find most efficient tools for the toolkit	Update existing regulation to include NBS promotion	
Forecast the consequences of coercive policies		Conduct an evaluation of relevant laws for recognising multiplicative effects promoting or hindering NBS	
Include NBS in land use policies	Require NBS in city- and master plans	Take actions to include NBS in regional plans.	Ongoing EU UIA and Urban Agenda for the EU initiatives should be supported, disseminated and replicated
Focus on the synergies of policymaking at various levels	Include NBS in planning documents of cities, following national policy framework	National planning policy framework steering the municipal planning to take NBS into account, e.g. national laws for urban planning	
Raise awareness of policies that could support NBS implementation	Offer knowledge for decision-makers to recognise the interrelation between various policies.		Launch various awareness-raising campaigns
Co-creation of norms	Engage local communities in the development of city plans and other policy instruments; develop participatory methods.	Ensure the representation of NBS-experts in the working groups for developing legislation in relevant fields (also other than environmental).	

Enforcement and economic strategies

It is crucial to have a **wide selection of policy instruments**, such as laws, norms, strategies, planning instruments, funding programs, incentives, and investment in research, to guide sustainable development through NBS (e.g. Kallio et al., 2014). Specifically, the following policy instruments have been identified as possibly effective and useful: land-use planning, authorisation procedures, information steering, fees, payment facilities (e.g. exemption from storm water charges), tax deductions, jurisprudence, penalties, agreements, persuasive guidance (e.g. expert assistance and knowledge-based facilitating) (Suvantola & Lankinen, 2008), as well as obligations to implement NBS along with new construction projects and investment support. If there is no coercive regulation or other strong incentives, prejudices and lack of knowledge or experience may profoundly hamper the wide-scale implementation of NBS.

Already existing **coercive policies** can either be an asset for or a barrier against NBS. For example, the national and EU policies regarding protected species constitute a positive case: a respondent in the ThinkNature project's survey about barriers and drivers reported a successful implementation of an NBS, where compensation in the form of a new habitat was required to be completed before the construction site was released (Bernardi et al., 2019). However, coercive regulation can seriously hamper the realisation of NBS (e.g. banning the use of available materials for substrate). In summary, the existing regulation may need to be updated to be more flexible, yet at the same time applied to its full extent, accompanied with penalties when needed. Towards this effort, both the EU and national legislation, as well as the judiciary, have a key role in achieving the desired NBS targets.

Regarding **economic strategies**, economic incentives to foster the implementation of NBS might assume different forms, such as: environmental taxes, price-based instruments, carbon trading schemes, biodiversity offsets, certification, payments for ecosystem services, fiscal benefits, etc. There might also be a combination of them. For instance, in Germany, the population has been successfully encouraged to adopt green roofs through tax incentives, fees, and regulations (WBCSD, 2017). Depending on the ecological domain, in which NBS are implemented, different economic incentives might be more effective and successful. For example, in the case of green roofs, or similar NBS interventions integrated in buildings, such as building-integrated agriculture, the upfront investment of the consumer can be stimulated; if both costs and benefits are shared equally among citizens, government, and businesses/developers (e.g. the building owner) (Toxopeus & Polzin, 2017).

Financial sanctions are also needed in cases where NBS are not realised properly, when the guidelines or contracts demand specific outputs. For example, the city of Helsinki has used penalty payment to force establishment of a green roof, when the investor had not completed the project with a vegetated roof, as written in the deeds regarding conveyances of land lots. Nevertheless, policy-driven instruments in the long term will not substitute market uptake. Several policies should be oriented towards measures seeking to gather evidence of cost effectiveness, environmental and ecosystem services, and suitable business opportunities, deriving from various examples (see also Chapter 6). Furthermore, financial statutory framework should support NBS capacity building through investing in experimental NBS and research. All these policies may result in implementing NBS instead of today's mainstream solutions and support, turning NBS into mainstream solutions for the challenges of tomorrow.

Land use strategies

Innovative approaches for sustainable land use and planning, including the use of NBS, are needed. Indeed, ongoing initiatives such as Urban Innovative Actions (UIA)[1] are rather crucial. A key to innovative approaches is the exploration of what is wanted or needed by whom, where, in which amount, and at what scale (Faehnle et al., 2014). Answering these questions will help with recognising issues of sustainability, social equity, and spatial-temporal functionality in terms of ecosystem services. A simple local example is the installation of NBS at the rooftop of a building; based on exploring and integrating the needs and wishes of those who reside in, work in, or visit the building. This kind of local NBS defining could of course be replicated at a wider scale based on municipal or national guidelines. Another example is the exploration of noise at the municipal level to specifically target noise cushioning locally with NBS. This exploration can be included in the planning process, proposing specific interventions for implementation.

Spatial policies, such as guidelines, which require the use of NBS and are implemented via master plans, are considered important for NBS development (Bernardi et al., 2019; Kallio et al., 2014). Inventories of existing NBS will reveal gaps related to land use, which can be used as a starting point for developing targets and timelines to achieve environmental equity. Updates of existing guidelines as well as the creation of new guidelines will be needed. The key organisations to fulfil this task are those of the local planning administrations. Furthermore, activating people to strive for NBS on private land is needed. Local, regional, and national authorities, the media, as well as the public who have the power to demand change, are the key actors (Bernardi et

[1] UIA is an EU Initiative that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Based on article 8 of ERDF, the Initiative has a total ERDF budget of EUR 372 million for 2014-2020.

al., 2019). Moreover, public authorities are expected to implement NBS interventions as part of local and regional planning and development and in general by integrating NBS actions in different types of sectoral planning. In this sense, elaborated decision support tools, such as multi-criteria analysis or environmentally extended cost-benefit analysis, should be taken into account to support NBS against traditional solutions (Droste et al., 2017).

The **long-term protection and support** of green spaces was also included in the responses to the ThinkNature project's survey (Bernardi et al., 2019). For instance, the decision to design and maintain a piece of land as a park with no major construction activities is essentially a policy issue. Maintenance and citizen support seem to be quite important for the long-term survival of green spaces, so the decisions should include these perspectives from the beginning and facilitate the necessary research and budgeting to guarantee their success. One way to guarantee protection is to give a special status to the land area or site.

Finally, it is important to create policy and **incentives** that assist in boosting the use and regeneration of brownfield instead of consuming greenfield. The role of NBS in the remediation, restoration, and prevention of formation of brownfield should be put high in the policy agenda, as they can provide beneficial ecosystem services, social inclusion, and economic redevelopment. Furthermore, the relationship between brownfield redevelopment/restoration and NBS has been highlighted by the Urban Agenda for the EU since its inception in 2016, limiting land consumption and promoting future city sustainability. As it is underlined in the Urban Agenda for the EU (2018): "the brownfield redevelopment presents a valuable opportunity to not only limit land take and prevent urban sprawl, but also to make cities more liveable. Brownfield regeneration also offers the chance to implement NBS."

Co-creation of norms and holistic policies for multifunctional NBS

State or municipalities' associations (e.g. environmental departments) could take the responsibility of creating quantitative and qualitative norms for key NBS in collaboration with other stakeholders. Specifically, the main stakeholders consist of the NBS users (residents, visitors, landowners, etc.), producers (green constructors, material producers, etc.), and researchers. Moreover, relevant consultants, NGO, and NBS pioneers could support such processes. An example is to provide norms for the self-sufficiency of neighbourhoods in water management, providing sufficient space for it locally.

Clear obligations and concrete guidelines are needed, since it may not be enough to state in a policy document (e.g. strategy) that a specific type of NBS needs to support biodiversity or be sustainably built. Instead, concrete alignments should be given about how to achieve the desired output (i.e. materials to be used, habitat characteristics, substrate qualities, plant species, etc.). For example, regarding releasing land development decisions, certain investments, such as sustainable drainage systems, green roofs, permeable surfaces, trees, or phyto-technical studies of the most suitable plants for the site, should be required. Importantly, the authorities need to follow up to ensure the implementation of the required NBS really happens. Setting goals, together with educating the authorities, investors, planners, and construction companies, will allow smooth collaboration. However, one barrier for efficient policymaking to promote NBS is the disconnection between short- term actions and long-term goals (see also Kuban et al., 2018). As noted during the A Coruña Forum in 2018, the short-term action and decision-making cycles within municipalities do not always match with the long-term requirements of the whole lifecycle of NBS projects (Jurik et al., 2018).

Also, the creation of norms, clear targets, requirements, and restrictions needs to be backed with arguments and information about the **multifunctionality of NBS**. This will help with understanding the importance of NBS and the fact that they are not only for one purpose, which in turn may help create political commitment (Szkordilisz et al., 2018). Furthermore, evaluation systems are needed for monitoring the achievement of the policy targets and supporting decision makers in taking the necessary measures. Overcoming the confrontation between green and 'grey' infrastructure may help with implementing NBS too (Depietri & McPhearson, 2017). The need for NBS should be recognised in land use policies because in cases where there is no political commitment concerning NBS, grey solutions may win over NBS. NBS should be considered as an essential part all municipal strategies (whether they concern flood risk mitigation, noise abatement, health, social equity, or other challenges). At the same time, the multifunctionality of NBS should be emphasised and result in budgeting that considers the multiple functions that NBS provide. Isolated policies may lead to separate budgeting approaches, in which each authority focuses on fulfilling their main targets in the cheapest way, ignoring the synergies that multifunctional NBS would provide, resulting in a lower total cost across the different sectors.

For instance, the green infrastructure of constructed wetlands and parks (Figure 7.2) performs equally to or even better than the grey alternative for water purification and flood protection. It provides additional benefits, specially valued by the local residents and stakeholders (e.g. recreational services), and it has similar costs. A case study in this sense is Gorla Maggiore (North Western Italy), where there is a set of constructed wetlands, surrounded by a park, providing pollution retention/removal, flood prevention, maintenance of biodiversity and recreation.

Figure 7.2. Yanweizhou multipurpose wetland park in Jinhua, China (https://oppla.eu/casestudy/18018)

Other examples are parks and green spaces, which activate people for mobility, are aesthetically interesting, support biodiversity, cool down the city environment, handle storm water, and may be lower in cost than targeting each of these benefits individually via other solutions. While many norms exist for public spaces (street width, parking place size, etc.), norms for parks and green spaces may be lacking. A positive case study about this topic is the Multifunctional Green Infrastructure for an Attractive Urban Region in Stuttgart (Germany), aiming to create a network of attractive, accessible, welcoming, and diverse open spaces that functions as a counterpoint to the region's grey infrastructure (Figure 7.3).

Figure. 7.3 Stuttgart Region: Multifunctional Green Infrastructure for an Attractive Urban Region (https://oppla.eu/casestudy/17477)

Policies supporting collaboration and co-design for local empowerment

Communication, collaboration, and co-design are key drivers (see also Chapter 7.3), hence supporting and demanding them is needed. These drivers can be achieved through empowering the public. For example, unused land can be turned into green space with the **involvement of the public**, existing green space can be co-managed with residents, new collaborative activities or space can be created, etc. The legal and policy frameworks should provide specific guidelines to authorities, and practitioners and authorities should control the overall process for accomplishing this type of involvement. A concrete example of the above activities is the project in The Golden Hill Community Garden (Figure 7.4). At this garden, there is an edible permaculture forest with tree species capable of surviving in waterlogged soils. Regarding the involvement of the local society, volunteers helped with the creation of the gardens and continue aiding the maintenance of the allotments and pond. Moreover, this community garden is accessible by wheelchair and the composting toilet can be accessed by people with disabilities. Also, in partnership with the local parents' group, family days for children with special needs and disabilities are organised. Consequently, in this case study, both environmental (e.g. increasing biodiversity) and social goals (public health and wellbeing, social cohesion, inclusion, and interaction, etc.) have been reached[2].

Figure 7.4. Activities for every age at the Golden Hill Garden (https://thegoldenhillcommunitygarden.com/)

[2] https://platform.think-nature.eu/nbs-case-study/19195

7.2. Governance perspectives from local to regional level

The concept of NBS is by essence multifaceted and covers a wide range of realities. Also, it is used in a lot of different contexts and its manifestations are various according to the location and time. Such a concept offers the possibility of dealing with a variety of issues such as resilience, climate adaptation and mitigation, human well-being, preservation of ecosystems and biodiversity, etc.; this makes it a complex object that should be understood in a **holistic way**. Indeed, NBS could be presented ideally as a tool, allowing a movement towards more resilient and sustainable territories and implying a shift in the trajectories of societies and human habits.

When it comes to nature and ecosystems, there are many interconnections and bounds among different parameters at different levels. One issue at a specific scale is usually related to another at a different level. This is why the issue of **governance and scales** needs to be addressed, in order to implement NBS in the best way and to cope with environmental issues in general. This field of research has grown over the last decades, as sustainability issues have become more and more significant in a context of globalisation. Indeed, those issues (climate change, threats to biodiversity, pollution, etc.) have the specificity to cut across traditional jurisdictions and thus require new forms of governance (Termeer et al., 2010). If NBS are thought of as a way to deal with such issues, then it could be interesting to go over some alternatives emerging to cope with the scale and governance issues.

Termeer et al. (2010) analyse three modes of governance dealing with scale issues. After referring to monocentric governance, which is more about the classic model of governance, they stress the **multilevel governance**, which is more interesting for the implementation of NBS. The term “levels” (supranational, national, regional, and local) is associated with spatial scales. The concept emphasises a displacement of state power and control through three ways: a) firstly, to international actors and organisations (e.g. EU and IUCN for the case of NBS, providing guidelines and definitions); b) secondly, to the regions, cities, and other local authorities; and c) finally to civil society and non-state actors. The word governing, in such a context, is about interactions among all the relevant levels of action. What seems to be paramount in this approach is the interplay between diverse stakeholders, who ultimately aim to achieve a collective goal. However, such a model is limited especially by the transaction costs related to the coordination of actors at multiple levels.

One step further, **adaptive governance**, which aims specifically at systems' resilience, emphasises the idea of uncertainty and then the need of flexibility in order to be able to adapt the systems as much as necessary to cope with the complexity and unpredictability inherent to socio-ecological systems. The concept of scale in this model is not limited to a spatial and jurisdictional aspect; also takes into account temporal, institutional, management, and network matters. Moreover, this model intends to go beyond the opposition between top-down and bottom-up approaches and avoid being insensitive to either local constraints, or to the existence of larger issues related to a particular local situation.

In the light of those different models of governance, **connecting the scales of action** appears to be paramount for building a coherent project on NBS: when they are thought of at the international or European level, NBS remain vague and imprecise. On the other hand, their implementation in fine scale (vegetal wall, urban garden, etc.) makes the concept not only more accurate, but also very punctual. Consequently, what would make NBS more ambitious and sustainability-oriented in the long term would be the interconnection between different systems. The interplay among several perspectives at different levels could thus be the key to enhancing existing measures by giving more feedback, and making different stakeholders acting at different levels (i.e. communicating and sharing knowledge and practices on NBS). Introducing feedback loops in the systems could help the movement towards a more consistent implementation of NBS (i.e. tools for resilience, human well-being, sustainability, and other NBS objectives) (see also Chapter 4).

On the whole, the implementation of NBS seems to require the involvement of multiple levels interplaying together with a view to achieving resilience through a solid set of measures connected at several levels. In order to introduce a strategy for implementing NBS at different scales, renaturation policies should be considered and developed, combining scales and domains of NBS. Towards this end, NBS could be considered as an attribute of other public or development policies too. For example, an eco-district strategy could implement NBS, a rainwater management plan could consider deploying NBS, etc. Territorial approaches, involving different levels of decision making combined with conflicting interests, can be driven with a **commitment to quality of life** for people living in the territory. Whether the focus is on thermal comfort and wellbeing in public spaces, or on changing the human living environment to adapt to risks, NBS can serve as an engine for public policies. Renaturing and adaptation strategies based on nature are designed to build resilience in the face of climate change. At the same time, they make it possible to involve local residents and to steer territorial and political decision- making towards a co-construction of these strategies (see also section 7.3).

Interconnecting scales for policymaking at various levels

Regarding policies, **international institutions** are often pioneers at proposing various policies for spreading the notion of NBS at both regional and local levels. In particular, the EU has developed a series of strategies, roadmaps, communication, and directives that include actions relevant to NBS to a greater or lesser extent and support NBS implementation in many ways[3]. For instance, the Habitats Directive requires a certain percentage of protected valuable habitat relative to the size of the country (EC, 1992); the Water Framework Directive and the EU Floods Directive require the implementation of concrete measures to achieve the goals of the directives (EC, 2000; 2007); etc. However, in the European region a great deal of effort is needed for the integration of NBS at all spatial levels. At the continental level, although there are plenty of related policies and funding mechanisms (e.g. Urban Innovative Actions, Horizon2020), NBS and its aspects should be included further in the existing EU policy framework (Davis et al., 2018; Urban Agenda for the EU, 2018). In respect of lower spatial scales, the inclusion of the NBS concept is varied among the diverse member states and depends on specific national initiatives, since there is a lack of commonly adopted standards, indicators, and targets imposed by EU (Davis et al., 2018). Therefore, the integration of NBS policies in the existing legal and institutional context of every country should be examined and implemented at national, regional, and local levels (Urban Agenda for the EU, 2018).

As for an example of **national initiatives in Europe**, the Netherlands has recently released a document titled "The Natural Way forward", which defines the 10-year vision of the country regarding nature conservation and sustainable use of nature's assets. Moreover, it has adopted the so-called "Building with Nature" approach, which sets the guidelines for making use of the dynamics of the natural environment for the development of its extensive coastal and river environment (WBCSD, 2017). As another example regarding the city level, in London the relevant infrastructure plan also includes a "Green Infrastructure Task Force", which aims to outline the city strategy to deliver greener infrastructure (Mayor of London, 2015). Also, in Milan, the EU's research and innovation funding strategy has been beneficial for the city's administration[4], and the city of Bristol has embedded the green infrastructure concept in its planning documents, facilitated by the national planning policy framework[5]. These are only some instances among the cases of policy initiatives across European countries or in the same country (e.g. "Building with Nature" and "Green Infrastructure" initiatives in the United Kingdom).

[3] https://ec.europa.eu/environment/nature/biodiversity/policy/index_en.htm

[4] https://oppla.eu/milan-nbs-urban-regeneration

[5] https://oppla.eu/bristol-nbs-ensuring-sustainable-future

Global, EU-wide, regional, or local policies or targets may boost responsibility, effort, and motivation of regional and local actors. **Raising awareness** of existing policies is needed, as policies do exist without institutions and people really noting them. Furthermore, increasing understanding of what the policies mean and how they should be applied in daily reality is urgently needed. Local/regional authorities should allocate work time to fully exploit all existing policies. Relevant associations and NGO could offer essential support in recognising the policies and the critical actions to reach the targets. Frequent policymaking, supported with international initiatives and stimuli, may help regional and local actors to focus on specific NBS and targets. One such example could be the annual selection process for 'Green capital of Europe'. In that selection process, a number of quantitative ratios could be tested, including various indicators: minimum area of green space in urban zone, number of trees/ha, maximum walking distance to the nearest park, area of green space/ inhabitant, etc. A similar approach is conceivable for non-urban zones and landscapes. However, the ratios should be selected so that they are equivalent across various geographical areas. Internationally available scientific and practical information on the efficiency of various policy instruments would help with creating functional local/regional instruments. Assessment of different policy instruments is needed, as there is a shortage of knowledge concerning the policies for NBS. For example, green roofs are supported by a wide range of various instruments at national and city levels, but there is not much information on the effectiveness of these instruments.

NBS definition and strategies at different scales

The meaning assigned to NBS determines the type of strategy that will be proposed. For example, the City of Paris has clearly adopted the concept defined by Eggermont et al. (2015). By putting human wellbeing at the heart of the NBS approach, this definition goes beyond the traditional debate between biodiversity conservation and its integration into political framework, integrating societal challenges such as the struggle against poverty or for wellbeing, protecting society from environmental change and risks over the long term. According to this concept, a broad spectrum of NBS is placed at a two-dimensional axis, one being the degree to which ecosystems are engineered, and the other being the number of ecosystem stakeholders and services which a given NBS is expected to attain – presented as being inversely proportional to the possibility of maximizing maximising a specific given service. This definition raises the question of the stakes in terms of public policy, especially on the subject of interest (i.e. the connection between the scale of the territory and the scale of decision- making).

Examples of NBS and multi-scale policymaking

Two case studies are analysed to detect how policy and territorial scales interconnect. The first (Paris) examines the strategy for dealing with two different hazards: flooding and heat waves. This municipal strategy involves several territorial scales and therefore different levels and scopes of decision- making, pertaining to the usage of NBS. Then, an example of interconnection in the Netherlands is presented: Room for the River Waal (Ruimte voor de Waal).

Paris is exposed to flooding along the Seine river. Also, the city is dense and covered by artificial surfaces, subject to heat island effects. Rendering more permeable surfaces and planting trees/vegetation are both a challenge and a necessity to cope with these two hazards. Paris has set an ambitious goal to plant more trees, as well as create green schoolyards, planted walls and rooftops, and shady spaces to help mitigate local heat waves. Regarding flooding prevention, Paris must rethink and manage its flooding risk by taking

Figure 7.5. A schoolyard of OASIS project (https://www.lemonde.fr/smart-cities/article/2019/05/30/face-a-l-urgence-climatique-les-grandes-villes-doivent-arreter-de-se-faire-plaisir-avec-des-projets-experimentaux_5469459_4811534.html) ©Ville de Paris - Henri Garat

a comprehensive approach to water management at two different levels: a) at the city level, reducing the quantity of run-off water, increasing water infiltration into the ground, reducing the volume of pollutants, etc.; b) at the scale of the river basin, involving several levels of local authorities, as well as taking into account agricultural activities and exploring other vectors for economic resilience in the area.

The City of Paris first conducted an analysis of its vulnerabilities in order to devise a strategy for resilience based on a comprehensive approach to the major challenges that must be confronted. Reducing flood risk and heat islands are examples of tackling the challenge by focusing not only on hazards management, i.e. at the scale of a territory larger than the Paris region, but also on expanding the effort beyond the dimension of risk management, in order to include issues of wellbeing and quality of life for Parisians. This approach of the NBS concept encourages a broad territorial scope, a hazard management encompassing interconnected local sites, and therefore gathers attention on modes of appropriation by users of the urban space. Such strategies are connected with the dynamics of international networks fostering a sharing of knowledge and experiences: in the case of Paris, it fits with climate change adaptation and mitigation efforts, through active participation in the network of 100 resilient cities. The choice of strategy directly impacts the choice of scale. The territorial stakes are linked to the political stakes and the meaning assigned to the concepts invoked.

As to facing heat islands, the OASIS project (Figure 7.5) identified schoolyards as a resource that the city could use to develop cool spots with permeable surfaces, contributing to wellbeing (i.e. offering residents quality spaces). The “Ecoles Oasis” programme is part of Paris’s overall strategy for resilience, with the ambition of combining climate change adaptation/mitigation and education, as well as achieving socio-spatial inclusion and public health. The project proposes a dual scale of intervention: a) neighbourhood scale (schoolyards intervention for creating cool islands, improving rainwater management and improving the quality of usages for school children); and b) city scale (linking of resource places in all Paris schools in order to create a string of cool spaces open to all). These multiple territorial scales directly impact on the scale of governance. In the case of Paris, such a project requires several levels of governance, complicating the chances of implementation, and needing intricate steering and engineering to come to fruition.

The challenge of coordinating these different territorial scales also means managing the associated systems of governance. Specifically, numerous local and national public agents are involved in the project, but also representatives of associations and residents. The technical and administrative dimensions can create obstacles or conflicting priorities in the process. The plan is to take a transversal approach within the city, involving different territorial scales (the State via the Ministry of Education, school directors and teaching staff, Paris via its various municipal departments, etc.). This example shows the extent to which citizen initiatives at the local scale can spur a more global approach. It also highlights the need to consider the small scale of the places where people live. The Paris authorities are planning to meet this local challenge by adopting a co-design approach involving the various departments of this major city. This phase requires explaining to all stakeholders the stakes and challenges of such a development, and its multiple scales. The children become actively involved in the transformation of their schools, learning about the immediate stakes but also gaining an understanding of the wider scale, as the city seeks to adapt to climate change by means of renaturation. Such exchanges among project stakeholders and beneficiaries require not only a partnership style of governance, but also the capability to take action.

In the Netherlands, the Room for the River Waal project offers a definition of the NBS associated with the plan for renaturing the riverbed. This approach, as part of a resilience strategy, also shows how the question of human wellbeing is tied to that of adapting cities via nature.

In the Netherlands, a large portion of the country lies below sea level and built areas are situated between winding waterways of the Dutch delta, thus the risk of high water has always been central to spatial planning in this territory. The location of Nijmegen, near the Rhine and crossed by the Waal, makes it particularly vulnerable to flooding. Therefore, the risk mitigation goals of the Ruimte voor de Waal project (Room for the Waal) include the improvement of environmental quality in the region and the development of means to cope with various climate change scenarios, based on flow rate calculations (Figure 7.6). Additionally, the project required close involvement of local residents, who were kept informed of progress via a newsletter and a number of public gatherings, offering residents the opportunity to express their opinions about the proposed course, which was in fact altered several times to take their comments into account, deciding about new land uses, interventions, and activities. Finally, coordination between the local and national scales of the project, between Ruimte voor de Waal and Ruimte voor de Rivier, was facilitated with multi-scale management of aquatic spaces, including local public in the institutional framework for waterways management[6].

[6] https://climate-adapt.eea.europa.eu/metadata/case-studies/room-for-the-river-waal-2013-protecting-the-city-of-nijmegen

Figure 7.6. Part of the Room for the Waal project area (https://www.flickr.com/photos/maldeno/26306868451/in/photostream/)

7.3. Policy and decision-making mechanisms

> "A key challenge is how we implement high level decisionmaking and demonstrate the importance of NBS to the wider thematic partnerships such as health, transport, and air quality. NBS has a significant role to play in partnerships that promote the livability and adaptability of a modern city" (Bernardi et al., 2019).

Policy framework and decision-making procedures are of the most crucial factors for the effectiveness of NBS planning and implementation. Indeed, NBS initiatives aligned with the implementation of **policy directives or goals** have more chance of being implemented (WBCSD, 2017). However, since NBS is a relatively recent concept, specific proposals pertaining to the above-mentioned aspects are needed in order to support the promotion and further use of these practices. In general, there is a need for increasing the inclusion of NBS in regulatory frameworks and administrative structures in order to deploy NBS multiple benefits (EC, 2015). Moreover, it is important for the deployment of NBS to be connected with other policy sectors (e.g. transport, water, agriculture, energy) and pertinent objectives (e.g. human health) that will attribute a rather multidimensional identity to NBS strategies. These linkages may assure the wider implementation of NBS practices; through the increase of disseminated and empirical knowledge, as well as the rise of funding perspectives (Davis et al., 2018).

Due to the novelty of the NBS notion, a relevant **operational framework** is also very useful for confronting practical issues and increasing the implementation of such interventions. The one developed by IUCN (Cohen-Shacham et al., 2016; 2019) stems from the comprehensive concept of ecosystem approach and can provide through its usage effective and sustainable NBS. In particular, the multiple functions of these operational guidelines can be analysed into: a) distinguishing NBS from other similar practices; b) assessing the effectiveness of NBS interventions (e.g. sustainability); c) proposing ways of strengthening NBS intervention; and d) considering the ecological and societal context in which NBS will be established. Regarding the structure of this framework, it could contain the following parameters:

- Multidimensional nature of the ecological interventions at diverse levels;
- Sustainability of the included interventions in the long- term;
- Appropriateness of interventions' scale according to organisational aspects;
- Influence of ecosystem services on society in a straightforward way;
- Flexibility of governance entity to be easily adapted to potential changes.

Focusing on **policy mechanisms**, there are a wide range of instruments that may foster the implementation of NBS. These might include (but are not limited to): a) development of a coherent and comprehensive information flow from governmental institutions to the public, but also among public institutions, highlighting the benefits and the costs of NBS; and b) multiple and varied forms and levels of cooperation among public and private sectors and citizens (Droste et al., 2017). Concerning the first point, more information about green infrastructure planning is necessary. Towards this objective, a coherent and comprehensive assessment of the main benefits and costs associated to NBS is rather useful (see also Chapters 3 and 6), because public administration is expected to carefully select between different solutions, justifying its choice in each case. For this reason, it needs more information and evaluation reports about the multiple and multidimensional advantages of NBS. Also, public administration should be required to establish a monitoring system to better analyse the services and benefits that existing NBS provide to the ecosystem, to the urban development and to the population in general; i.e. improved quality of life, public health benefits, air quality, quantification of energy savings, environmental impacts, etc. (see also Chapter 5). Also, information about the value that NBS provide in terms of natural capital stocks and flows should be carefully accounted into municipal budgets (Droste et al., 2017). Having such information available for environmental agencies would definitely encourage the implementation of such practices.

As to cooperation potential, new consciously designed **multilevel governance mechanisms** are needed in order to implement innovative environmental and natural resource policy mechanisms (Lockwood et al., 2010). Establishing these forms of mechanisms allows identification of the needs of all actors involved, and eventually supports the policy uptake. These new forms of cooperation might also lead to the creation of new sorts of decision-making institutions. Indeed, public authorities may not be identified anymore as the most important source of environmental decision making institutions (Armitage et al., 2012). Decision- making must now demand and accommodate the participation of various actors, networks, and hybrid partnerships among public and private actors, and must include opportunities for information exchange and shared learning. More specifically, trans-disciplinary and inclusive partnerships and governance approaches have proved to empower the uptake of NBS, especially when their impact is linked to climate change adaptation and mitigation challenges (Kabisch et al., 2016a). In other words, synergies are significant in respect to sustainability objectives, as long as there is a cooperation among diverse societal groups entailing different expertise and the assignment of roles to partners is flexible and complementary towards the best support of the adopted goals in each case (Frantzeskaki et al., 2014).

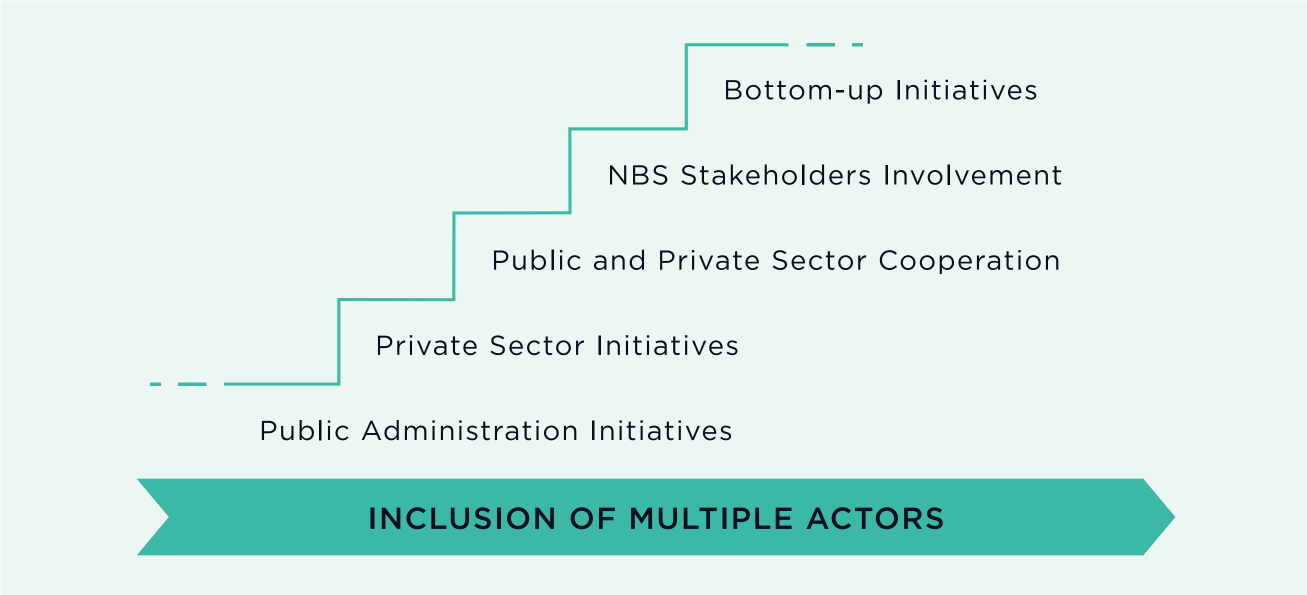

Figure 7.7. Alternative decision-making processes regarding the inclusion of multiple actors

Of course, the combination of stakeholders, who can be involved at each spatial level, may differ (Table 7.2). Also, there are many alternative decision-making mechanisms for the wider implementation of NBS in the context of governance that can be identified (Figure 7.7), based on (Sekulova & Anguelovski, 2017):

- Public administration units: Public administration at regional or local level (e.g. municipalities) implements top-down decision- making processes excluding the substantial involvement of other actors.
- Cooperation between public and private sector: Public administration cooperates with private firms and organisations in order to ensure sufficient funding.
- Involvement of multiple NBS stakeholders: Public administration adopts a collaborative decision-making approach, involving stakeholders such as public, experts, decision makers, etc.
- Bottom-up initiatives emerged from civic society: Environmentally sensitised groups of citizens initiate actions in respect of NBS realisation.
- Private sector initiatives: Private firms and organisations plan and/or implement NBS practices in the framework of their business activity seeking profit and mitigation of risks to their operation.

In general, **cooperative models of governance** are proved to work more effectively, when they are implemented within an enabling system of government regulations and are compatible with other governance mechanisms and tools, such as strategic planning and the use of economic incentives (Armitage et al., 2012). Regarding planning, the involvement of stakeholders can be really helpful for: a) enriching the planning process with additional information; b) enhancing the final planning proposal;

and/or c) implementing commonly accepted solutions, which reflect at least the suggestions and desires of participants (Krommyda et al., 2019; Panagiotopoulou et al., 2018; Stratigea et al., 2018; etc.). As for economic incentives, a schematic review of different instruments of environmental governance based on market incentives and exchanges suggests that their success depends significantly on the internalisation of positive environment preferences among relevant stakeholders, including citizens and consumers (Lemos & Agrawal, 2006).

Table 7.2. Examples of actors and stakeholders recognised to have leverage in NBS implementation in the field of policy at various regional and organisational levels

LOCAL LEVEL	NATIONAL LEVEL	EU-LEVEL	GLOBAL LEVEL
Municipal administration: authorities and decision- makers e.g. in urban planning, forestry, green area management, construction, water management, social and health care, transportation, sports, safety	National administration: authorities and decision- makers, e.g. in environment, construction, law, education, social and health-care, transportation, energy, agriculture, waste, sports, cultural heritage	EU authorities and decision- makers, e.g. environment (incl. disaster risk reduction, climate, biodiversity, green infrastructure, ecosystem services, circular economy), sustainability, urban and regional policy, construction, health and well-being, agriculture, energy, transport, waste, education	United Nations, e.g. The United Nations Environment Programme UN Environment, e.g. Finance Initiative
City councils, boards and committees (e.g. above-mentioned fields)	Political parties	EU-financed projects in relevant fields	Networks of cities
Regional administration, e.g. for metropolitan areas covering several municipalities	Regional administration, e.g. counties	Networks of cities, e.g. European Green Cities (EGC).	Umbrella organisations of NGO and industry/ trade
Local communities, e.g. neighbourhood associations	National organisations of municipalities		
	Associations of local and regional authorities		

Involving citizens in decision making

Among the actors to be involved in the decision-making process, **citizens** play a major role, and they should be informed, empowered, and eventually involved in NBS actions, planning, and implementation. Indeed, NBS initiatives focused on citizens can definitely contribute to social cohesion, replenishing the connection between citizens and nature, increasing their awareness of the multiple benefits of NBS, and raising a public request for a better environment. Moreover, by giving citizens the opportunity to express their opinions and thus raise their voice, governments, as well as local and regional authorities, are able to obtain information to which they might not otherwise have access (Van Ham & Klimmek, 2017). Also, the involvement of citizens is important in order to learn about the level of their comprehension and their opinion regarding the climate and its impacts, as well as their preferences regarding NBS and other green infrastructure actions, considering their costs and benefits (Derkzen et al., 2017).

This kind of involvement can be accomplished with numerous **methodological tools** permitting the involvement of multiple stakeholders (EC, 2015; Somarakis & Stratigea, 2019). For example, the city of Vitoria-Gasteiz (Spain) developed an online platform, which allowed more than 300 citizens to take part in a survey covering a range of topics related to urban planning, social inclusiveness, and ways to improve the city liveability, through a network of bike and pedestrian connections and public transport (Van Ham & Klimmek, 2017). In another case, the cities of Bratislava and Prague are using online tools such as emotional maps, which are used by citizens to express their opinion about how they feel in certain places. This information can be then used by public authorities and planners to enhance planning effort and results. However, it is important to note that, in order to develop and implement such citizen inclusive models successfully, citizens must feel their voices matter and are taken into consideration by decision-makers. Therefore, it is essential to go beyond the public administration's good intention to have the public involved in the decision-making process, as the willingness to listen to public concerns is not sufficient. Instead, a citizen engagement process needs a structure that assures the integration of technical expertise, regulatory requirements, and public values (Lemos & Agrawal, 2006).

One positive example, of how citizens' engagement has been successfully integrated in the decision-making process of city planning including NBS, is the case of Park Spoor Nord in Antwerp, Belgium (Figure 7.8). Spoor Nord is a former-industrial area and, until few years ago, was a highly complex and multi-ethnic neighbourhood in the north part of the city of Antwerp. In 2001, the

Figure 7.8. Park Spoor Nord in Antwerp (https://oppla.eu/casestudy/19438)

city developed a project to transform the abandoned former railway sidings into a 24-hectare urban park within the city, as part of a public-private partnership supported by the European Regional Development Fund (ERDF). Throughout the whole transformation process (i.e. before, during, and after the planning phase), the city of Antwerp engaged the citizens through different consultation sessions, and then incorporated the comments and feedback from the citizens in the planning process. Nowadays, citizens still play an active role in the management of the park, together with a city officer who has the role of park manager and takes charge of recreational activities in the park with the active participation of local residents and neighbouring associations, networks, and services.

Public and private sector cooperation

Partnerships between the public sector and the private companies have several **advantages**. For example, private companies may provide the local community with several types of expertise, project management skills, and private funding, essential for the solution delivery. Moreover, the cooperation between public and private sector is proposed at least in the EU countries in order to ensure the financing of these solutions (EC, 2015). In this context, all the private stakeholders, who would benefit from the implemented solution need to be identified and engaged. It is essential that not only big scale / multinational companies are selected to take part in the partnerships, but also enough space needs to be dedicated to small scale / local enterprises as partners. This will result in preventing local knowledge and experience, embodied in small-scale enterprises, from being pushed out of the process, ignoring existing assets (Baud, 2000).

Also, the synergy between public and private sector has the potential to **drive governance changes** in the direction of NBS. Such is the example of Volkswagen's involvement in the Puebla-Tlaxcala Valley in Mexico, where the company invested in the restoration of an illegally deforested area, to provide fresh water for the nearby city of Puebla (Figure 7.9), while securing a reliable water supply for the stability of the company's production plant in the region (Van Ham and Klimmek, 2017). In detail, the company partnered with the local governance body and formed a ten-person environmental planning team, which developed the project, with the additional support of the Environment Secretary for Mexico. The team evaluated different alternatives and opted for a system of natural infrastructure alternatives (i.e. trees, pits, and earthen banks) to enhance rainwater capture. After six years, this initiative resulted in the plantation of 490.,000 trees, the installation of 91.,000 pits, and 430 earthen banks to preserve water in an area of over 750 hectares (WBCSD, 2016). Another example of a similar policy has been set up in Costa Rica, where a first national programme for Payments regarding Ecosystem Services in the world has been established. In this programme scheme, the water users (e.g. hydropower companies) pay fees to upstream landowners within the same watershed to manage land in a way that supports the local water management goals. This programme helped the country to generate finance needed for forest restoration activities that enhanced vital ecosystem services. This particular policy enabled the restoration of a cumulative area of 1.2 million hectares in Costa Rica (Browder et al., 2019). Finally, in Europe, there is a collaboration between cities and companies delivering infrastructure. For instance, there are many examples of delivering NBS in the transport sector (e.g. green tramlines), helping both a city to achieve its sustainability goals and the company to mitigate operational risks such as distortion of tramlines from overheating.

Figure 7.9. Reforestation project in Mexico (https://oppla.eu/casestudy/18030)

CHAPTER 8

RECOMMENDATIONS FOR NBS UPTAKE

8 RECOMMENDATIONS FOR NBS UPTAKE

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1 - Enhancement and harmonisation of the knowledge and the evidence- base on NBS for the formulation of global NBS standards

An improved knowledge base, including rigorous scientific evidence of NBS performance, is an essential overarching necessity for upscaling NBS implementation. Established evidence helps convince decision- makers of the viability of NBS. The need for a stronger knowledge base is also true for the monitoring of NBS effectiveness. Information of NBS impacts on the short and long term needs to be delineated, whether it be their effect on the environment, society, and economy or in helping to solve pressing issues, such as climate change (Bourguignon, 2017).

This knowledge base must seek to define expectations and evaluate their outcomes, addressing the complexity and uncertainty inherent to NBS as living systems, and identifying potential synergies and trade-offs across multiple installations, and guiding risk assessments (including the challenges associated to NBS implying the introduction of species and creation of new ecosystems) (Le Roux et al., 2016). Structuring the knowledge base about NBS impact on nature, society, and economy is essential in addressing the inherent complexity of NBS (Kabisch et al., 2016a; 2016b).

During the survey conducted Paris Forum on NBS (April 2019), the key results related to knowledge gaps and recommendations were:

- 98% of the respondents strongly agree or agree that “Testing and upscaling pilot projects on NBS need to continue at wider scales and for different land uses/cover (forest, wetlands, coastal, etc.), with their outcomes widely shared”
- 90% of the respondents think that “Investing in fundamental research on the role of biodiversity and ecosystem services for the deployment of NBS” very important or important.
- More than 70% of the respondents think that we have at least partial “Knowledge and evidence base across European diversity of contexts (social, economic, environmental and climatic) for NBS efficiency and cost effectiveness with respect to , quality, , prevention, of life and wellbeing, mitigation, , land use”

The European Commission has already defined the main targets of reaching such goals by developing the NBS Community of Innovators, building the NBS Repository of case studies, and coordinating NBS actors into Task Forces. The knowledge base should be advanced with more demonstration projects (i.e. inclusion of NBS in Horizon Europe) towards understanding the links between NBS and ecosystem services (Lafortezza et. al., 2018), enhancing our knowledge on successful and unsuccessful NBS practices, developing innovative technologies and know-how, and investigating NBS transferability issues (Albert et al., 2019). There are several parallel initiatives that work on NBS globally and therefore the coordination of all effort is challenging. However, it is essential to harmonise the multiple NBS initiatives into common goals and a common NBS definition in order to develop a consensus on concrete guidelines and global standards for NBS.

2 - Development of adapted indicators for monitoring and evaluation

Developing a common reference framework for NBS monitoring and impact evaluation is a priority. There is a need to develop and spread indicators that i) capture the whole picture of NBS benefits, synergies, and trade-offs, and ii) are developed coherently across sectors and scales (Raymond et al., 2017a; 2017b). Defining the effects of NBS on the short and long term is essential (Kabisch et al., 2016a). Beyond the benefits, there is also a need to assess the risks associated with a given NBS and alternative solutions, looking at the potential impacts across time and space, and accounting for future environmental changes (Eggermont et al., 2015), i.e. to develop indicators that quantify the benefits and the trade-offs. The same indicators can also be used to evaluate the efficiency and the efficacy of NBS (Le Roux et al., 2016). Such indicators should also not overlook investigating the range and importance of NBS impact regarding citizens (Kabisch et al., 2016a; 2016b).

A coherent development and uptake of these indicators across scales should also be sought, avoiding different stakeholders from developing different operational criteria independently. Such incoherence has begun to arise (e.g. parallel exercises on specific NBS-focused criteria cited in Cohen-Shacham et al., 2016), although likely many of these specific criteria can be useful in assessing other interventions and there is likely an overarching set of principles to guide implementation of all of these approaches. The latest technological, research, and innovation advancements in multiple fields, such as in monitoring technologies (i.e. earth observation for baselines development, comparisons, etc. – see also Chapter 5), are expected to support the NBS monitoring schemes and meet the requirements (see also Chapter 4) for the development of sophisticated, robust, and appropriately designed assessment methodologies.

3 - Interaction across disciplines and adoption of participatory approaches

There is a plurality of views and knowledge systems around human-nature interactions, central to NBS. Accounting for these when developing and assessing NBS is essential, calling for multidisciplinary approaches to developing our understanding of NBS.

This can be interpreted in a wide sense, e.g. promoting knowledge systems where fundamental and applied research are not opposed (Eggermont et al., 2015), using elements of traditional nature-based practices (such as customary resource management systems) to offer more appropriate and accepted solutions (Cohen-Shacham et al., 2016) or mobilising the ecological engineering community to develop NBS, as natural ecological processes and human interventions are tightly intermingled for many types of NBS (Le Roux et al., 2016). This should also not be done independently from social and economic matters (Nesshöver et al., 2017).

The involvement of multiple stakeholders of NBS is essential to their success. Transdisciplinary approaches (i.e. working across stakeholder groups) can help overcome challenges and deploy opportunities (Nesshöver et al., 2017), for instance in integrating local and scientific knowledge towards more effective solutions (Rizvi & van Riel, 2017). There is evidence that stakeholder empowerment facilitates the sustained success of NBS projects (Cohen-Shacham et al., 2016). This calls for exploring ways of stakeholder (citizens, decision makers, etc.) involvement, as well as communication modes of successful and unsuccessful examples of NBS, acknowledging the legal and administrative frameworks of NBS implementation and handling the competition with other land uses (Kabisch et al., 2016a; 2016b).

More specifically, involving stakeholders (e.g. experts) and end users (e.g. local population) is a required step for: a) enriching available information with scientific or experiential knowledge (e.g. information about the specific features of a place); or/and b) strengthening democratisation and acceptance of the decided plans that have been agreed on (i.e. policies, measures, and actions) by the local community. Both purposes can lead to sustainable realisation of NBS practices and can be used in decisions about the planning/designing, implementation, and assessment of NBS established in areas of interest.

4 - Operationalisation of existing and new knowledge

There is a need of to develop technical products that are ready and easy to replicate and install, since the cost of single NBS projects can be very high. Digitisation or smart technologies may provide cost-efficient solutions by reducing the maintenance costs, e.g. via automated irrigation systems. In a nutshell, fostering replicability and even industrial scale-up of NBS practices would be high impact drivers. In general, if NBS technical performance alongside life-cycle cost (installation, running, and maintenance costs) are demonstrated to be competitive, the choice of NBS practices over grey and other conventional solutions will be supported. Also, development of cost-efficient technologies will make the solutions accessible for less wealthy countries and municipalities (Bernardi et al., 2019).

The lack of operational clarity in implementation hinders the large-scale of uptake of NBS concepts and approaches.

The responsibility of interpreting how to put an idea into practice is often left with the policymakers or managers, which may result in time lags and a chilling effect that impedes the progress of NBS (Cohen-Shacham et al., 2016). The need for clear definitions and principles but also parameters and methodological frameworks to guide their application has long been called for (Brandt et al., 2013; Davis, 2008), and there are works that explore this direction, e.g. operational framework developed by Cohen-Shacham et al. (2016), or in Raymond et al. (2017a; 2017b).

Yet, discussions at the ThinkNature Paris Forum, on business models for NBS for instance, showed that different understandings in the audience on the definition of NBS, their sustainability, or the role of nature in supporting these, led to apparent difficulties in developing operational business models that integrate long-term life cycles and maintenance costs of NBS. Inventing and sharing operational tools and guidelines for the implementation of NBS appears essential, in terms of efficiently transferring scientific concepts and approaches into practice (Rizvi & van Riel, 2017) but also in directly connecting people and expertise, e.g. associating scientists to NBS design processes and finding ways of designing multiple NBS, involving multiple groups, and resulting in various benefits to multiple beneficiaries (Kabisch et al., 2016a; 2016b).

5 - Efficient dissemination of knowledge

Dissemination of knowledge is a critical factor for the establishment of every new concept. In other words, it is really important to inform not only all potential NBS stakeholders but also civil society in order to consolidate this type of solution as a common and popular practice in comparison to other typical and pre-existing practices. Examining the knowledge (i.e. transferability and lessons learned issues) derived from the ThinkNature case studies portfolio[1], some specific aspects of knowledge dissemination are highlighted, which can be deployed for the further uptake of NBS.

Primarily, wide communication of NBS is needed for both public administration units (e.g. municipalities) and citizens. Regarding citizens, enhancing public knowledge about NBS can increase public awareness and affect the attitude of citizens (i.e. priorities and perspectives of the public) concerning these solutions, which can influence local decisions about green infrastructure and NBS in particular.

In the context of enabling effective communication, technical information should be translated for the above-mentioned target groups. All available information should be localised and interpreted so that impacts and risks are clear and easily understandable. As to impacts and focusing on multiple

[1] https://platform.think-nature.eu/case-studies

benefits, it is clear that NBS provide a series of benefits (promoting biodiversity, improving adaptation to climate change, aiding recreational activities, etc.) and support the handling of many global challenges (see also Chapter 3). This information should be disseminated to at least all potential end users (e.g. authorities), which may be lead actors to adopt new NBS. However, training regarding emerging techniques is needed for planners, developers, and construction professionals to make things happen (Bernardi et al., 2019).

Towards wide-spreading NBS knowledge, networking can be really crucial too. Specifically, the participation in networks, associations, and consortiums, which are linked to NBS approach, may contribute to useful NBS knowledge acquisition.

6 - Creation of funding opportunities and efficient business models

In general, business cases are needed for all sizes of NBS (and especially for involving the private sector) and their integration in the decision-making process is crucial, in order to ensure necessary funding. Particularly at a local level, financing can be available to NBS initiatives through decentralised funds and credit schemes, while at larger scales public-private partnerships can be fostered to finance relevant NBS (Cohen-Shacham et al., 2016).

Further exploring efficient financing/funding and business opportunities for NBS is a prerequisite for the wider dissemination of NBS. In the framework of this investigation (see also Chapter 6), valuing ecosystem services to make a business case for investment in ecosystems is really important, since the cost of the techniques for NBS should be reasonable (including maintenance) – and in fact NBS may often be more cost-efficient than other solutions, triggering practitioners to choose NBS over other more established solutions (Bernardi et al., 2019). Also, in the case of natural infrastructure, economic planning needs to account for ecosystem services. With the costs and benefits of ecosystem services valued, a business case can be made for investing in ecosystems and watersheds as natural infrastructure, as part of sustainable financing (Cohen-Shacham et al., 2016). This type of valuation can be proven very useful for public, private, and other organisations in order to define their contribution (with their own resources). Specifically, they can participate in funding programmes, increasing the total investment amount for NBS propagation.

7 - Harmonise policies and facilitate synergies across scales and across multiple agendas

The policy landscape remains highly fragmented across scales and sectors. Harmonising legislation at international, national, regional, and local scales is a key need for facilitating NBS uptake and sustainable development in general. Updating existing regulation and setting NBS-oriented policies is needed at local scale. There is also conflicting regulation across scales (EU vs national scale) that need harmonisation. EU regulations (e.g. directives) should be systematised, structuring a cohesive legislative framework. Furthermore, these regulations should be adopted and further specified at national, regional, and local levels, incorporating and being compatible with corresponding needs, anticipations, and objectives. Direct policy levers from the highest national policy level according to EU regulations can remove direct barriers and significantly accelerate NBS uptake, fostering improved inter-sectoral coordination.

Better harmonisation of policies across economic, environmental, and social agendas is particularly important regarding NBS. It is important to recognise the multiple dimensions of NBS impacts and co-benefits across economic, environmental, and social agendas. The social impacts of green-space management strategies, for example, contribute to a range of public health and well-being outcomes that can also drive public interest or bolster political support for their implementation. Even in Europe, poverty remains an issue and it is usually the poor and vulnerable who are at greatest risk and the least resilient to disasters. An overarching framework for promoting NBS is the 2030 Agenda for Sustainable Development and the SDG since NBS offer high potential to contribute to the achievement of most of the SDG targets.

It is therefore important to perceive NBS as a multifunctional tool that supports holistic and far-reaching policies that integrate socioeconomic, security, and environmental goals. Focusing on the synergies and efficiency of policy making at various levels and promoting vertical and horizontal cooperation among different policy makers and sectors is a key factor for implementing holistic NBS-oriented strategies. A rather critical attribute, for building trust between all parties involved and the public, is transparency. Particularly, all decisions should be widely disseminated and decision-making processes should be sufficiently transparent.

8 - Innovative collaborations and governance systems

NBS are multi-faceted projects and solutions that challenge existing, often monolithic, governance systems. Innovative governance systems, compatible with the multiplicity of approaches, scales of time and space, and beneficiaries inherent to NBS's effectiveness need to be explored. This requires assessing current policy effectiveness and coherence, while fostering cross-sectoral and cross-scale approaches.

Better understanding governance systems that support NBS requires analysing supportive policy frameworks, as well as factors of political and social resistance to change at relevant levels, and addressing the consistency of different policies and approaches for integrated spatial planning and efficient NBS deployment and overcoming some trade-offs (Le Roux et al., 2016). Exploring cross-sectorial and cross-scale approaches is required for many NBS to be successful, involving a variety of training, capacity building, and communication efforts, including the need for new and innovative partnerships and governance structures and for multi-scale co-management designs when managing resources across boundaries (Cohen-Shacham et al., 2016). An open approach to collaborative governance of NBS was proposed by Frantzeskaki (2019) as the key aspect in operating and maintaining NBS in a way that ensures social inclusion, well-being, and resilience. Adaptable governance approaches were also suggested by Kabisch et al. (2017) as an important aspect in future NBS science and policy agendas.

Designing such innovative collaborations and governance systems is key to simultaneously achieving biodiversity and social impacts and increasing the overall success of an NBS (Cohen-Shacham et al., 2016). Consideration of socio-environmental justice is also an important element of such structures. Yet, as reflected in the ThinkNature Paris Forum discussions, biodiversity is not only a co-benefit of NBS, but instrumental to their design, and there is a need to explore to what extent the reactive "conserve/restore to solve current problems" approaches should be complemented by more proactive "conserve for future adaptation needs" approaches. (Le Roux et al., 2016).

EPILOGUE

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Illustration: © Luc Schuiten

How can we make our dreams come true? This is an important question as the decisions we make today construct the reality of tomorrow. Thus, decisions should be based on evidence about possible futures, and acquiring such knowledge likely requires multiple approaches. One approach is to investigate possible futures through the needs of the users of NBS, which is a fruitful approach as it provides information on the potential roles NBS could play in people's lives, i.e. the services and solutions that are desirable. Studying people's dreams can give a rich and lively insight into the potential of NBS especially when there is a need to explore such NBS that do not yet exist, or when vulnerable groups (e.g. children or the elderly) are concerned, or in general for the purpose of innovation.

To offer some inspiration and food for thought, in the text below we refer to data that was collected using the method of empathy-based stories (MEBS), regarding people's dreams about their future living environments in greener cities in different projects, collected from children, those in need of supported living, or the "ordinary" adult urbanites (for the MEBS, see e.g. Mesimäki et al., 2017).

"It is beautiful there with more forests to play in, more animals, more nature, more trees and less streets. There are more leaves to play with in fall. There would be more forest than nowadays. I love green spaces because one can play there. There are more bushes to build huts and fallen trees to climb on. One can find interesting fungi and birds in the forest. On the trees one can find more for hiding or bushes so it looks beautiful. It is fun to play in the forest with my friends. Sometimes one can find water with fish and other animals. "

"To get into the forest I walk out of our front door. I want to be in the forest because the air is good. I go for a walk with mom, dad and -sister-."

"Me and my friend did horseback riding through the forest. Then we sat down on a bench. It was very peaceful and the birds were chirping, the sun was shining and we had a wonderful day. We rode back. It was the best day I ever had. I wanted to go there because it was very peaceful and cars couldn't be heard and industry couldn't be seen. "

"I wish there would indeed be green bus stops in the future. I imagine sitting in a bus on my way downtown. Along the way, I see a variety of green bus stops. In one of them, there is a birch forest painted on its walls. It makes me think of the coming summer. The second would be painted or photographed moss, in the third, a variety of dwarf shrubs... I am thinking of my grandchildren with whom I stand at the stop waiting for a bus. Time would pass comfortably when we look at the pictures and I would tell them about nature. The stops will give the busy people a tranquil moment and take their thoughts into the fascinating world of nature. There could be some light vegetation on the roofs of the stops. Would it be possible to have real evergreen plants next to stops?? ... [Closer to the sea], one could see seaside and archipelago plants with twisted dwarf pines and lovely flowers at the stops. Every stop would tell its own story about the diverse wonderful nature of [our country]. I believe that a beautiful stop will tell the passengers a lot about the people in the area, and their appreciation. A beautiful green stop creates pleasure and would make at least me smile."

"I scuttle in torrential rain to find shelter at the bus stop. Funny how there is no sound of the loud patter under the bus stop roof as the vegetation takes in the droplets. I have a funny feeling: I'm like a troll under the tussock. I would

not be surprised at all, if a forest goblin crawled in under this same tussock. The rain stops while I'm waiting for the bus, and I move from underneath the roof, standing now next to the stop. I think how much fun it would be to climb on top of the bus stop and ponder the damage to the green roofs of the stops when the unruly city dwellers can't resist climbing on top of these gigantic boulders of the urban jungle? Perhaps after all, I'm in the minority with my thoughts... The roof is not quite unpopulated though, but a bird or two or more fly to it from time to time. I would love to see on top of the roof better. What's growing up there and what does it look like?"

This kind of data can be very rich and analysed in-depth from different viewpoints and for different applied purposes, and the stories show the values and aspirations of the actual users. Such future-oriented imagining techniques allow for the freedom of mind, which in turn allows exploration of possible futures and internal values that may not be revealed through more defined survey and interview techniques. In a ThinkNature survey (Bernardi et al., 2019), we used a combination of fixed/ closed survey questions with open future-oriented questions, and present below some of the ideas revealed by the open-ended questions.

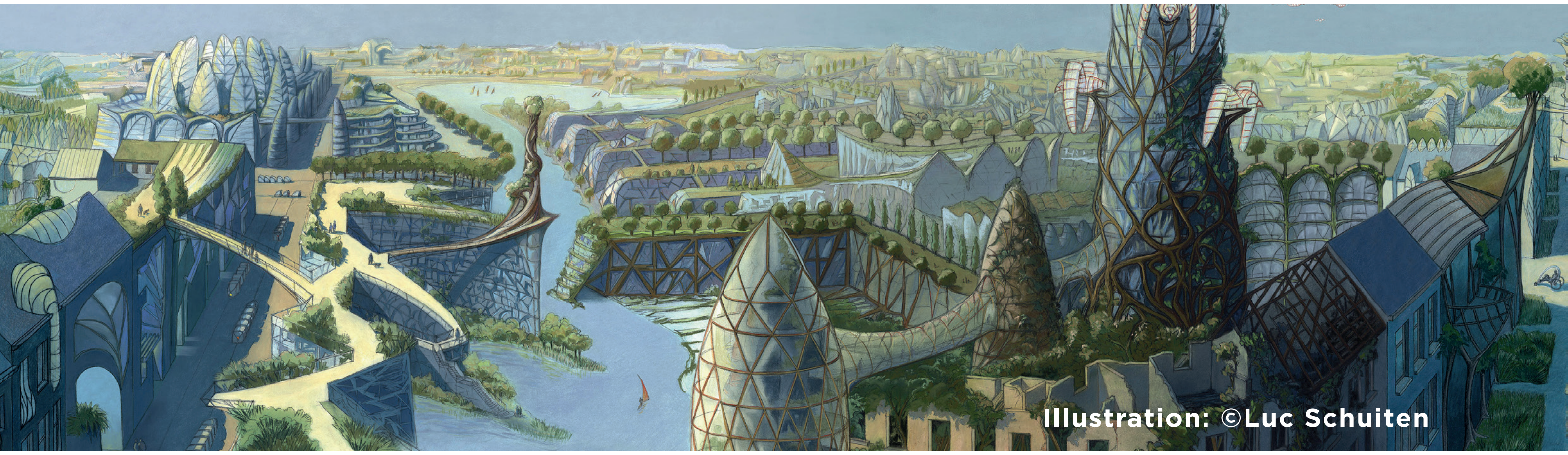


Illustration: ©Luc Schuiten

Ideally, future landscapes and NBS therein provide access to people independent of their capacities to get to nature, and every new spatial or architectural plan includes accessible NBS. Children, the elderly, and disabled, as well as people with different cultural backgrounds will be able to safely enjoy the opportunities for recreation, recovery, inspiration, joy, play, and aesthetic delight (Bengtsson & Carlsson, 2013; Jansson et al., 2016; Laaksoharju & Rappe, 2017; Rappe et al., 2006).

The current situation is blatantly sub-optimal: a resident in an assisted living unit reveals her feelings in an interview:

> *"I've pretty much given up hope already, as I'm here. I've probably given up hope so much, you see, that I do not even think about [something one could have or do outside]. (..) I just live day by day like this (--) I have probably put that part of my mind away. That I don't even care to think about it [to be able to get out alone]..."*

Emerging NBS provide hope and happiness, as described by a resident in a new block of flats with green roofs, green facades, and a kitchen garden:

> *"I turn my face towards the sea, I breathe, I feel. Suddenly I hear nature, smell scent of plants. I calm down immediately. I cease the moment. I am grateful for my mere existence. It is wonderful to be alive. Again today I thank my luck for that I may live here. Even now, it feels like a dream, a daydream, a lottery win. I have been looking for a home for so long, to home, always moving forward, without finding. I get grounded, though my feet don't touch the ground. Even before I knew it, I was missing. Only when I came here I knew; I'm at home." (MEBS, unpublished data).*

A liveable - safe, walkable, green, experientially diverse - landscape could be designed as a multifunctional recreational area with an entire system of NBS, comprising other ecosystem services with aesthetically pleasing and inspiring views to NBS through windows, immediate access to nature from the doorstep, and extensive green networks through which one can move on foot, bike, or other soft mobility. Spatial planning and digital apps make it easy to optimise soft mobility routes via green spaces and NBS (cf. Korpilo et al., 2017; 2018). For example, in cities, connectivity across blocks high up, from a vegetated rooftop to another, could provide new kinds of "highways" for walking and social networking, and a totally new layer in the urban matrix. Urban gardening and harvesting would provide opportunities for recreation in a variety of spaces from private (e.g. rooftop gardens on private buildings) to public (e.g. edible forests in public space).

While above we present dreams purely from the user's perspective, the actual functionality of the landscapes and NBS therein is realised through the plants, animals, fungi, and microbiota that keep the ecosystems functional. Thus, it is necessary to consider the living nature in the landscape and the capacity of NBS to support biodiversity. The on-going mass extinction of species and populations globally (Ceballos et al., 2015; 2017) calls for immediate action! Ideally, in all upcoming landscape plans, NBS provide abundant habitat for declining species and populations. Plantings based on indigenous species, and explicitly focusing on species that are in decline, will mimic key characteristics of natural habitats using a biotope template approach (cf. Nagase & Tashiro-Ishii, 2018). Ignatieva & Hedblom (2018) and Yang et al. (2019) provide ample inspiration on how lawns can be turned into meadows that are rich in species and simultaneously require a lower input of natural and economic resources. Ideally, recreational forests and parks also provide opportunities to host a range of species that live on decaying wood that is scarce in commercial forests (Hauru et al., 2014; Horák, 2017; Reise et al., 2019). Furthermore, taking indigenous plant species to production could lead to new livelihoods (cf. Maloupa et al., 2008). The immediate need for action means that research collaboration between practitioners and academics concerning the capacity of innovative NBS for supporting biodiversity is in high demand (Gaston et al., 2005; Horák, 2017). We envision authorities everywhere supporting local innovation by demanding such collaboration.

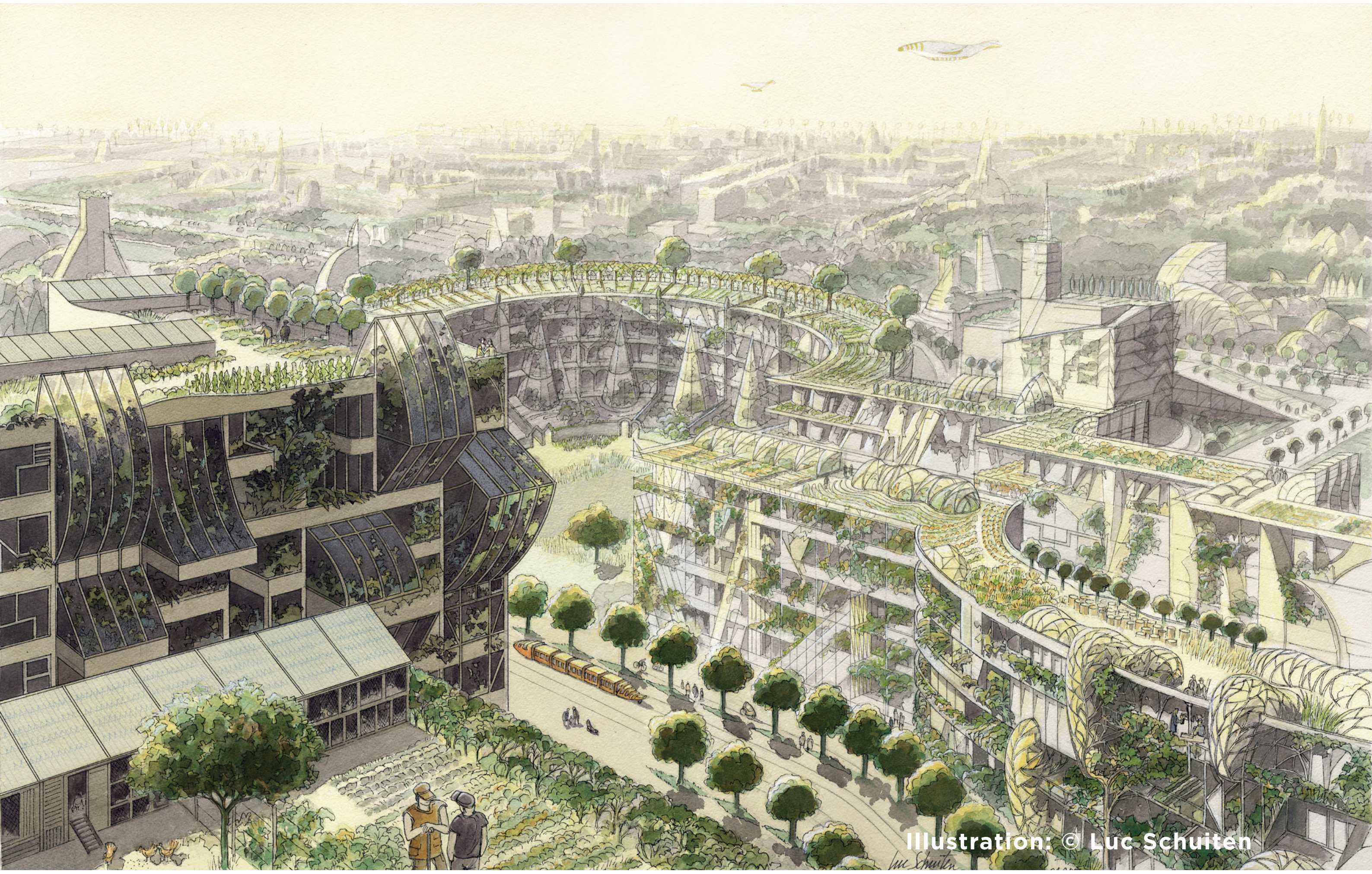
When realising the dreams above, sustainability in future landscapes is the most important aspect of NBS, as they are meant to provide a variety of positive effects and minimal negative impacts (see also Chapter 3). In the ThinkNature survey (Bernardi et al., 2019), people envisioned a variety of future NBS, and several ways to realise them:

> *"EU should consciously and comprehensively promote sustainable green roof and facade solutions, and NBS in general, based on local recycled materials and plants, and seriously including the users in the design". [Answer to an open question]*

For example, restored streams and wetlands, as well as reforestation, green roofs, and roof gardens were seen as essential parts of future landscapes. According to the conclusions of the survey, ideally, explicit policies for sustainable NBS and market drivers at EU, national, and municipal levels set strong standards that ensure sustainability of all NBS. Spatial planning policies, via master plans, can efficiently support NBS propagation. Ideally, there would also be standards for self-sufficiency of neighbourhoods in water management and thus also enough space for drainage and water storage. In addition to innovative new kinds of NBS, restoration of degraded ecosystems plays an important role in climate change adaptation-mitigation and risk management in future landscapes. In the ideal future scenario, coastal zones will be naturally restored to buffer against flooding due to storms and tsunamis, reforestation of mountainous areas will be accelerated to avoid landslides and flooding due to cloudbursts, and agroforestry will increase food and income security. The strongest effort is put into decreasing and stabilising the CO^2 levels in the atmosphere as soon as possible, yet a rich variety of different NBS at the landscape level will be used to comprehensively prepare for climate change adaptation and mitigation.

Spreading knowledge is essential for guiding societies towards sustainable solutions instead of unsustainable ones. Education about climate change, NBS, and sustainability plays an important role in the transition towards sustainable communities. New subjects that explicitly focus on these topics and provide the learners with skills for systemic thinking should be included in education curricula at all levels. There are compelling arguments that we need to widely revise learning and education policies and practices to achieve sustainability transformation (Arya & Maul, 2016; Boström et al., 2018; Perkins et al., 2018).

Critical thinking, global perspectives, dialogic methods, inter- and trans-disciplinary approaches are needed to support effective and transformative learning and comprehensive understanding about possible futures.



ANNEX 1: NBS CLASSIFICATION SCHEME

Type 1 – Better use of protected/ natural ecosystems - *No or minimal intervention in ecosystems, with the objectives of maintaining or improving the delivery of a range of ES both inside and outside of these preserved ecosystems*

Protection and conservation strategies in terrestrial (e.g. Natura2000), marine (e.g. MPA), and coastal areas (e.g. mangroves) ecosystems

- Limit or prevent specific uses and practices
- Ensure continuity with ecological network
- Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction
- Maintain and enhance natural wetlands
- Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds, and vegetated dunes from further degradation, fragmentation, and loss.
- Natural Protected Area network structure
- Mangrove forests protected area MPA network structure

Type 2 – NBS for sustainability and multifunctionality of managed ecosystems - *Definition and implementation of management approaches that develop sustainable and multifunctional ecosystems and landscapes (extensively or intensively managed), which improves the delivery of selected ES compared to what would be obtained with a more conventional intervention*

Agricultural landscape management

- Agro-ecological practices
- Use grazing management and animal impact as farm and ecosystem development tools
- Change crop rotations
- Soil improvement and conservation measures
- Increase soil water holding capacity and infiltration rates
- Agro-ecological network structure
- Mulching
- Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage
- Integrate biochar into agricultural soils

- Enrichment planting in degraded and regenerating forests
- Forest patches
- Hedge and planted fence
- Flower strips
- Cover crops
- Wind breaks
- Deep-rooted plants and minimum or conservation tillage
- Agroforestry

Coastal landscape management

- Encourage development of early successional sand dune habitats (dry dunes and wet slacks) where carbon sequestration rates are high.
- Enhance or facilitate habitat expansion, including the facilitated range expansion of mangroves, as warming conditions and changes in storm occurrence permit.
- Integrated coastal zone management

Extensive urban green space management

- Ensure continuity with ecological network
- Planning tools to control urban expansion
- Historical urban green network structure
- Choices of plants
- Heritage park
- Urban natural protected areas
- Introduced vs. local plants
- Vegetation diversification
- Green corridors and belts
- Planning tools for biodiversity, green infrastructure, and ecosystem services
- Tools to engage citizens
- Mapping green features

Monitoring

- Assessment of NBS benefits
- Ecosystem services valuation methods
- Bio-indicators

Type 3 – Design and management of new ecosystems - *Managing ecosystems in very intrusive ways or even creating new ecosystems (e.g., artificial ecosystems with new assemblages of organisms for green roofs and walls to mitigate city warming and clean polluted air).*

Intensive urban green space management

- Integrated pest management
- Integrated weed management
- Integrated and ecological management - spatial aspects
- Integrated and ecological management - time and frequency aspects
- Create and preserve habitats and shelters for biodiversity
- Choices of plants
- Large urban park
- Pocket garden/park
- Community garden
- Green cemetery
- Hedge and planted fence
- Private garden
- Urban forest
- Flower field
- Street trees
- Intensive green roof
- Semi-intensive green roof
- Extensive green roof
- Roof Pond
- Climber green wall
- Green wall system
- Planter green wall
- Vegetable garden
- Urban orchards
- Urban vineyards
- Meadow

- Urban farm
- Introduced vs. local plants
- Vegetation diversification
- Plant and bio-filter features
- Moss green roofs
- Urban network structures

Urban planning strategies
- Direct human intervention
- Use of fauna
- Account for distribution of public green spaces through the city
- Planning tools for climate change adaptation/mitigation and ecosystem services
- Mapping of urban green connectivity and biodiversity

Urban water management
- Develop urban blue infrastructure
- Streams, including re-meandering, re-opening Blue corridors
- Sustainable Urban Drainage Systems
- Integrated water management

Ecological restoration of degraded terrestrial ecosystems
- Quarry restoration
- Phytoremediation
- Systems for erosion control
- Soil and slope revegetation
- Strong slope revegetation
- Replace hard engineered river stabilisation with softer alternatives (e.g. willow-based)
- Plant trees/ hedges/perennial grass strips to intercept surface run-off
- Use of pre-existing vegetation

Restoration and creation of semi-natural water bodies and hydrographic networks
- Restore wetlands in areas of groundwater recharge
- Reconnect rivers with floodplains to enhance natural water storage
- Re-vegetation of riverbanks
- Re-meander rivers (where they have been artificially straightened) to help reduce speed and height of flood peaks
- Restore grassland/low input arable in drinking water catchments
- Use engineered reedbeds/wetlands for tertiary treatment of effluent
- Target ponds/wetland creation to trap sediment/pollution runoff in farmed landscape
- Constructed wetlands and built structures for water management
- Rivers or streams, including re-meandering, re-opening Blue corridors
- Floodplain restoration and management
- Reshape river and riverbanks in urban areas

Ecological restoration of degraded coastal and marine ecosystems
- Create new intertidal habitat through afforestation, or planting of saltmarsh or seagrass at appropriate elevations in the tidal frame
- Restore micro-topography, creek networks, sediment inputs, and nutrient exchange in abandoned aquaculture ponds.
- Re-establish and restore previous intertidal habitat by de-poldering or coastal realignment
- Ecological restoration of degraded coastal and marine ecosystems
- Coastal sand engine
- Dune replenishment

ANNEX 2: NBS APPROACHES, CHALLENGES, AND ECOSYSTEM SERVICES PER TYPE

Food, crops, wild foods, and spices (F)	Carbon sequestration and climate regulation. (CS&R)	Nutrient dispersal & and cycling (N)	Recreation (R)
Water (W)	Water purification (WP)	Seed dispersal (SD)	Intellectual and aesthetic appreciation (I)
Pharmaceuticals, biochemicals, and industry. Products (P)	Air quality regulation (AQ)	Soil formation and composting (SFC)	Spiritual and symbolic appreciation (S)
Energy (E)	Erosion prevention (EP)	Primary production (P)	
	Flood protection (FP)		
	Maintaining populations and habitats (MP&H)		
	Pest and disease control (P&DC)		
	Crop pollination (CP)		

NBS TYPES		NBS APPROACH										
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management	Sustainable agriculture/agro-forestry/aquaculture
Type 1: Better use of protected/natural ecosystems Sustainable agriculture/agro-forestry/aquaculture												
Protection and conservation strategies	Limit or prevent specific uses and practices				X						X	
	Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction	X	X		X	X	X		X	X	X	X
	Maintain and enhance natural wetlands			X	X				X			
	Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds, and vegetated dunes from further degradation, fragmentation, and loss.	X					X					
	MPA network structure			X	X	X	X		X	X		

NBS CHALLENGES										ECOSYSTEM SERVICES		
Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
X	X		X	X	X		X	X		(W)	(AQ), (EP), (FP), (CS&R)	(R), (I)
X						X	X		X		(EP), (FP), (MP&H), (CS&R)	
X	X	X				X			X	(W), (F)	(WP), (FP), (MP&H)	(R), (I)
		X	X							(F)	(FP), (MP&H)	(R), (I)
	X	X						X				(R), (I)

NBS TYPES		NBS APPROACH									
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management
Type 2: NBS for sustainability and multifunctionality of managed ecosystems											
Agricultural landscape management	Agro-ecological practices	X			X		X		X		
Agricultural landscape management	Use grazing management and animal impact as farm and ecosystem development tools				X						
Agricultural landscape management	Change crop rotations				X						
Agricultural landscape management	Soil improvement and conservation measures				X						
Agricultural landscape management	Increase soil water holding capacity and infiltration rates		X	X	X		X		X		
Agricultural landscape management	Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage				X						X
Agricultural landscape management	Enrichment planting in degraded and regenerating forests	X			X						
Agricultural landscape management	Forest patches	X			X						
Agricultural landscape management	Deep-rooted plants and minimum or conservation tillage				X					X	
Agricultural landscape management	Agroforestry	X									

	NBS CHALLENGES										ECOSYSTEM SERVICES		
Sustainable agriculture/agro-forestry/aquaculture	Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
X	X	X					X	X		X	(W), (F)	(AQ), (CS&R), (WP), (FP)	(R), (I)
X							X	X		X		(MP & H)	(I)
X		X					X	X		X	(W)	(WP)	
X		X					X	X	X	X		(WP), (EP), (CS&R)	(I)
X		X					X	X	X	X	(W)	(FP)	
		X									(W)	(MP&H)	(I), (S)
X	X	X			X		X	X				(MP&H), (CS&R)	(R), (I)
X							X	X				(MP&H), (CS&R)	(R), (I)
X								X		X		(MP&H),	(R), (I)
X	X											(MP&H), (CS&R)	(R), (I)

NBS TYPES		NBS APPROACH									
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management
Type 2: NBS for sustainability and multifunctionality of managed ecosystems											
Coastal landscape management	Integrated coastal zone management	X			X		X		X		
Extensive urban green space management	Ensure continuity with ecological network	X	X	X	X	X	X	X	X	X	X
	Planning tools to control urban expansion	X		X	X					X	
	Planning tools for biodiversity, green infrastructure, and ecosystem services	X	X	X	X				X		
	Heritage park		X		X						
	Green belt	X		X		X	X				
	Tools to engage citizens		X	X	X			X		X	
Monitoring	Assessment of NBS benefits	X	X	X	X		X	X	X	X	X
	Ecosystem services valuation methods				X						
	Bio-indicators	X									

	NBS CHALLENGES										ECOSYSTEM SERVICES		
Sustainable agriculture/agro-forestry/aquaculture	Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
X	X	X					X	X		X	(W), (F)	(AQ), (CS&R), (WP), (FP)	(R), (I)
	X	X		X	X	X		X	X		(W)	(CS&R), (WP), (AQ), (FP), (MP&H),	(R), (I)
	X	X		X	X	X		X	X		(F)	(AQ), (FP), (MP&H)	(R), (I)
X	X		X			X	X	X		X		(FP), (MP&H)	(I)
X	X	X		X	X	X		X	X			(MP&H)	(R), (S)
	X	X		X	X			X	X			(AQ), (FP), (CS&R)	(R)
	X			X		X	X	X	X	X			(R), (I)
X	X	X	X	X			X		X		(W)	(FP), (MP&H), (EP)	(I)
		X					X		X				(I)
	X			X	X				X	X	(P)	(MP&H)	(R), (I)

NBS TYPES		NBS APPROACH									
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management
Type 3: Design and management of new ecosystems											
Intensive urban green space management	Integrated and ecological management - spatial aspects	X	X	X	X	X	X		X	X	X
	Create and preserve habitats and shelters for biodiversity		X						X		
	Choices of plants							X	X	X	
	Large urban park	X	X	X	X	X	X		X	X	X
	Pocket garden/park		X		X	X					
	Community garden	X	X		X	X				X	
	Private garden	X					X				
	Urban forest	X								X	
	Street trees				X	X				X	
	Intensive green roof/ Semi-intensive green roof/ Extensive green roof	X			X			X		X	
	Climber green wall	X								X	
	Green wall system	X						X	X		
	Planter green wall							X		X	
	Vegetable garden		X		X	X					
	Urban orchards										
	Urban network structures							X	X	X	

	NBS CHALLENGES										ECOSYSTEM SERVICES		
Sustainable agriculture/agro-forestry/aquaculture	Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
	X	X	X	X	X	X		X	X		(W)	(AQ), (FP), (MP&H), (CS&R), (WP)	(R), (I), (S)
X		X		X	X				X		(E)	(AQ), (FP), (MP&H), (CS&R)	(R), (I), (S)
	X	X											(I),
	X	X		X	X	X	X	X	X	X	(P), (E)	(AQ), (FP), (MP&H), (EP) (CS&R), (WP)	(R), (I), (S)
	X	X		X	X	X		X	X		(E)	(AQ), (FP), (MP&H), (CS&R)	(R), (I), (S)
X	X	X		X	X	X		X	X		(E)	(AQ), (FP), (MP&H), (CS&R)	(R), (I), (S)
	X	X		X	X	X	X	X	X			(WP), (AQ), (FP), (CS&R)	(R), (I)
	X	X			X				X		(P)	(AQ), (CS&R),	(R), (I)
	X								X			(AQ), (CS&R),	
	X	X		X	X	X		X	X		(W)	(AQ), (FP), (CS&R), (WP)	(R), (I)
	X			X	X	X		X	X			(AQ), (CS&R),	(R), (I)
	X			X	X	X			X			(MP&H), (CS&R)	(I)
									X			(AQ)	(I)
X		X		X		X		X	X		(E)	(MP&H), (CS&R)	(R), (I), (S)
X		X		X	X	X		X	X		(F), (E)		
									X			(MP&H), (CS&R)	(R), (I)

NBS TYPES		NBS APPROACH									
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management
Type 3: Design and management of new ecosystems											
Urban planning strategies	Use of fauna		X		X	X					
	Account for distribution of public green spaces through the city	X	X	X	X	X	X		X	X	X
	Mapping of urban green connectivity and biodiversity	X	X	X	X	X	X				
Urban water management	Develop urban blue infrastructure	X	X	X	X		X	X	X	X	
	Sustainable Urban Drainage Systems	X	X	X	X	X	X	X		X	
	Integrated water management	X									X
Ecological restoration of degraded terrestrial ecosystems	Systems for erosion control				X		X		X		X
	Use of pre-existing vegetation	X		X	X	X	X		X		X

	NBS CHALLENGES										ECOSYSTEM SERVICES		
Sustainable agriculture/agro-forestry/aquaculture	Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
X		X		X		X		X			(E)	(MP&H), (CS&R)	(R), (S)
		X		X	X	X	X	X	X			(AQ), (MP&H), (CS&R), (FP)	(R), (I), (S)
	X			X	X	X	X	X	X	X	(W)	(WP), (AQ), (CS&R), (FP)	(I)
	X								X		(W), (E)	(WP), (AQ), (FP), (MP&H)	(R), (I)
		X		X	X	X		X	X		(W)	(CS&R), (WP), (AQ), (FP), (MP&H)	(R), (I)
		X		X	X	X		X		X	(W)	(CS&R), (WP), (FP)	(R)
	X	X		X							(W)	(CS&R), (WP), (EP), (AQ), (FP), (MP&H)	(R), (I)
		X		X	X	X		X	X		(W)	(WP), (AQ), (EP), (FP), (CS&R)	(R), (I)

NBS TYPES		NBS APPROACH									
		Climate adaptation approaches	Community based adaptation	Ecosystem based adaptation	Ecosystem based management	Ecosystem based mitigation	Ecosystem based disaster risk reduction	Ecological engineering	Ecological restoration	Infrastructure related approaches	Natural resources management
Type 3: Design and management of new ecosystems											
Restoration and creation of semi-natural water bodies and hydrographic networks	Re-meander rivers (where they have been artificially straightened) to help reduce speed and height of flood peaks	X		X	X	X	X	X	X		X
	Use engineered reedbeds/wetlands for tertiary treatment of effluent					X	X	X	X	X	
	Constructed wetlands and built structures for water management			X	X				X		
	Rivers or streams, including re-meandering, re-opening Blue corridors				X			X	X	X	X
Ecological restoration of degraded coastal and marine ecosystems Ecological restoration of degraded coastal and marine ecosystems	Re-establish and restore previous intertidal habitat by de-poldering or coastal realignment	X		X	X		X	X	X		X

	NBS CHALLENGES										ECOSYSTEM SERVICES		
Sustainable agriculture/agro-forestry/aquaculture	Climate mitigation and adaptation	Water management	Coastal resilience	Green space management	Air quality	Urban regeneration	Participatory planning and governance	Social justice and social cohesion	Public health and wellbeing	Potential of economic opportunities and green jobs	Provisioning services: (F), (W), (P), (E) *	Regulation and maintenance: (CS&R), (WP), (AQ), (EP), (FP), (MP&H), (P&DC), (CP)*	Cultural: (R), (I), (S)*
	X	X		X	X	X		X	X		(W)	(FP)	(R), (I)
		X							X		(W)	(WP), (FP), (MP&H)	(R), (I)
		X				X			X		(W), (E)	(WP), (MP&H)	(R), (I)
X		X		X	X			X	X		(F)	(WP), (FP), (MP&H), (CS&R), (EP)	(R), (I)
X	X		X	X	X			X			(F), (W)	(EP), (FP), (CS&R), (MP&H)	(R), (I)

ANNEX 3: KEY ELEMENTS FOR SUCCESSFUL PRACTICES

KEY ELEMENTS AND DRIVERS FOR SUCCESSFUL PRACTICES

IDENTIFY AND PRIORITISE CHALLENGES AND GOALS

Co-define primary goals and priorities, weighting the input from all affected parties

Evaluate anticipated benefits, co-benefits and trade-offs to make informed decisions

Consider the optimisation of various benefits simultaneously, taking into account the implementation context

Reach concensus, reconciling conflicting goals and interests

Prepare to cope with complexity and ambiguity of the addressed challenges

MAKE OPTIMAL USE OF AVAILABLE KNOWLEDGE, TECHNICAL SOLUTIONS AND TECHNOLOGIES

Enable multi- and transdisciplinary knowledge exchange and co-design for a mutual understanding of the available alternatives, their costs and their impacts

Promote design and testing of applied technologies in NBS, through innovative collaboration with engineers, scientists and academics regarding novel technologies

Chose technical products that are ready to use and easy to be install to reduce the cost of NBS and promote further adoption.

Provide technical support for the construction and implementation of NBS

Use Cultural Heritage as a source of inspiration for renaturing Cities through the use of historical technologies

Digitisation or smart technologies support cost-efficiency as these can reduce maintenance costs, e.g. via automated irrigation systems

NBS design and implementation to include multiple goals whose effectiveness can be measured

Provide appropriate training regarding emerging techniques to planners, developers, and construction professionals

CONCEPTION EVALUATION

Even across scales, stakeholder involvement enables knowledge exchange and co-creation

Stakeholder mapping and engagement

Recruit local partners to ensure efficient interaction with local administration

Take into account insights of all interested parties early on to enable informed decisions, optimise planning and ensure general acceptance

Build on the input of experts from different disciplines and scientific domains

Ecological and other natural sciences to offer innovative NBS and also evaluate the outcomes

PLANNING

Work with citizens on the design and management of temporary uses of vacant spaces

Facilitate the exchange process to engage all into a constructive dialogue

Engage with networks that have created or have acquired experience implementing NBS

Promote sense of ownership

Implement open space strategies that aim to increase accessibility for citizens and ensure quality (e.g transform schoolyards into cool islands, open to the community)

Social and Economic sciences to facilitate and support stakeholder involvement and evaluation of NBS

Green roofs:
- use soils derived from local area,
- adopt a growing medium depth of min 10 cm,
- structure short mounds (height: 30 cm – width: 3 m) as habitat of many living species,
- plant mixed types of native vegetation,
- involve authorities and experts in planning and implementation stages, for extensive roofs

IMPLEMENTATION

Ensure the sustainability of NBS

Careful selection of materials (locally sourced, reused, recycled, with minimum eco footprint)

Provide technical instructions with lists of suitable plants (organisms) for the local conditions and instructions for their maintenance

Provide instructions on how to avoid invasive species, and guidelines to use invasive species databases, such as www.nobanis.org/

CITIZEN PARTICIPATION FOR BETTER COMPREHENSION OF RISKS AND CONI

ADAPTABILITY TO THE CONTINUOUS ECOLOGICAL, ECONOMIC AND SOCIA

FLEXIBILITY WHEN IT COMES TO RE-EVALUATING GOALS AND PROPO

IN THE IMPLEMENTATION AND UPSCALING OF NBS

IN THE IMPLEMENTATION AND UPSCALING OF NBS

Technical knowledge from architects and engineers to be interlinked with knowledge on social and environmental systems for optimum synergies

Use technology applications to inform and increase public awareness regarding challenges addressed and the effectiveness of NBS (e.g. smartphone software)

Quadrant analysis and time-lapse photography are effective solutions for ecosystem-based NBS monitoring

Pursue thorough formal assessment for large scale NBS

Monitor and assess

Define appropriate criteria that will enable measuring of the success towards the pre-defined goals. Criteria should assess the ecological, social, and economic performance of the applied solutions

LCA, MIPS, or other overall system cost-benefit and environmental evaluation should be a basic requirement for all NBS to ensure their overall sustainability

Ensure long term monitoring especially for large scale NBS as there are long term effects that need to be taken into account

FLICTING EFFECTS

L CHALLENGES

SED ACTIONS

SUCCESSFUL IMPLEMENTATION OF NBS

Create a solid technical knowledge-base through demonstration projects to support NBS and also help in estimating costs of alternatives.

Handbooks for action containing: info on who should be involved, financing opportunities, instructions for applying resources and evaluation of outcomes.

Implement formal assessment of technical performance alongside life-cycle cost (installation, running and maintenance costs) to showcase the effectiveness of NBS

KNOWLEDGE BASE

Key actors for the upscaling of NBS: municipalities, state authorities, research organisations, NGO, EU

Support NBS innovators at EU, national, regional, and local levels to overcome technical barriers

Effectively disseminate knowledge of existing technical solutions e.g in exhibitions, conferences, and other events

Establish a common protocol for design, implementation, and maintenance of NBS for academia, business, and NGO

Integrate follow-up monitoring in the organisational culture of financing bodies

Information on unsuccessful projects is equally useful in terms of improving practice. Such examples help address barriers and build confidence among stakeholders

"The knowledge and experience derived from planning, implementation, and impact assessment stages of various NBS case studies is a valuable resource for future relevant initiatives"

TRANSFERABILITY & REPLICATION OF NBS

The lack of evidence base and the misperception of benefits, technical inadequacy, governance barriers, economic barriers, reduced participation, and awareness, are barriers that impede the uptake of NBS. These aspects, once properly addressed, can become drivers that promote wide adoption of NBS.

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